METALLURGIA

THE BRITISH JOURNAL OF METALS

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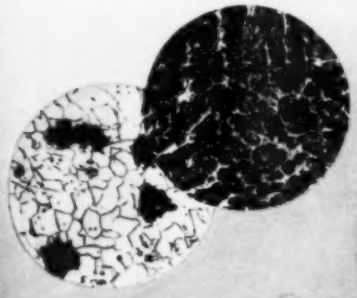

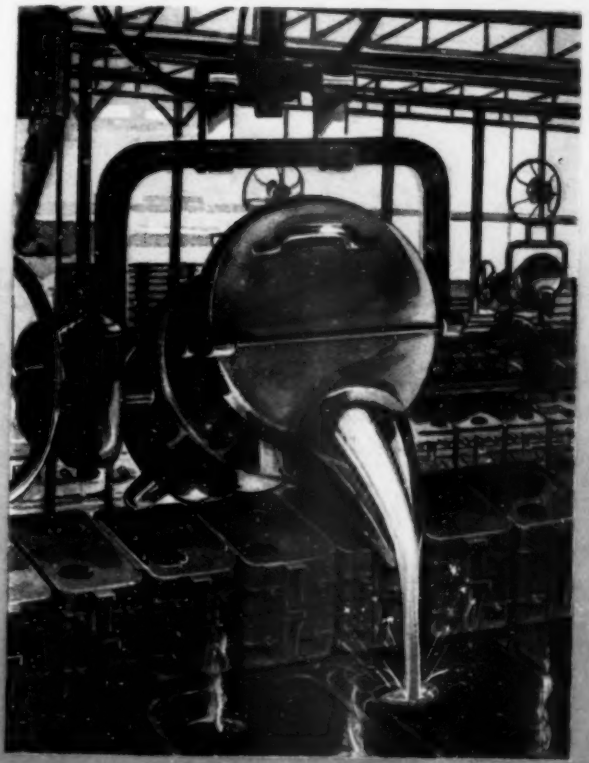

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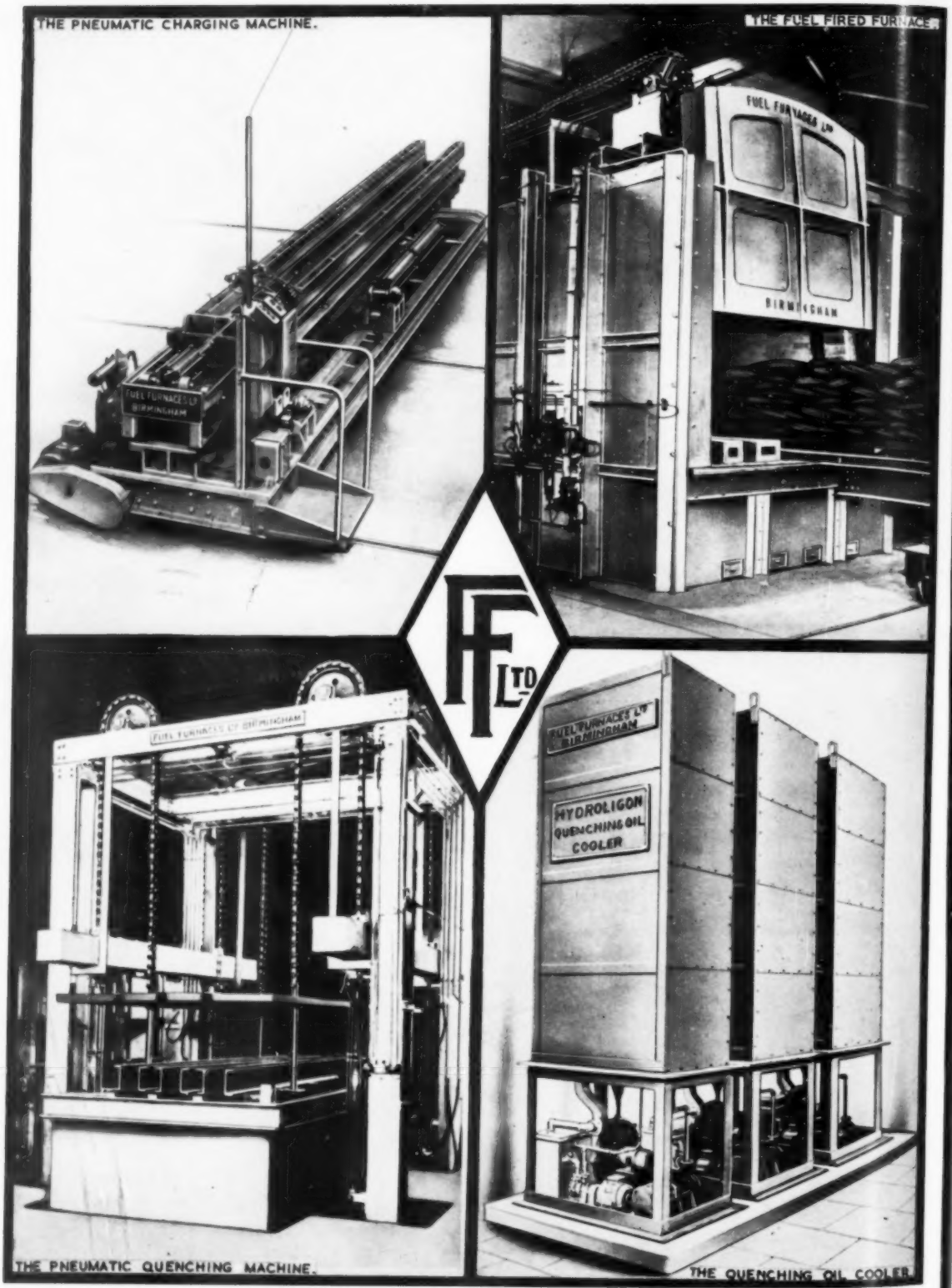
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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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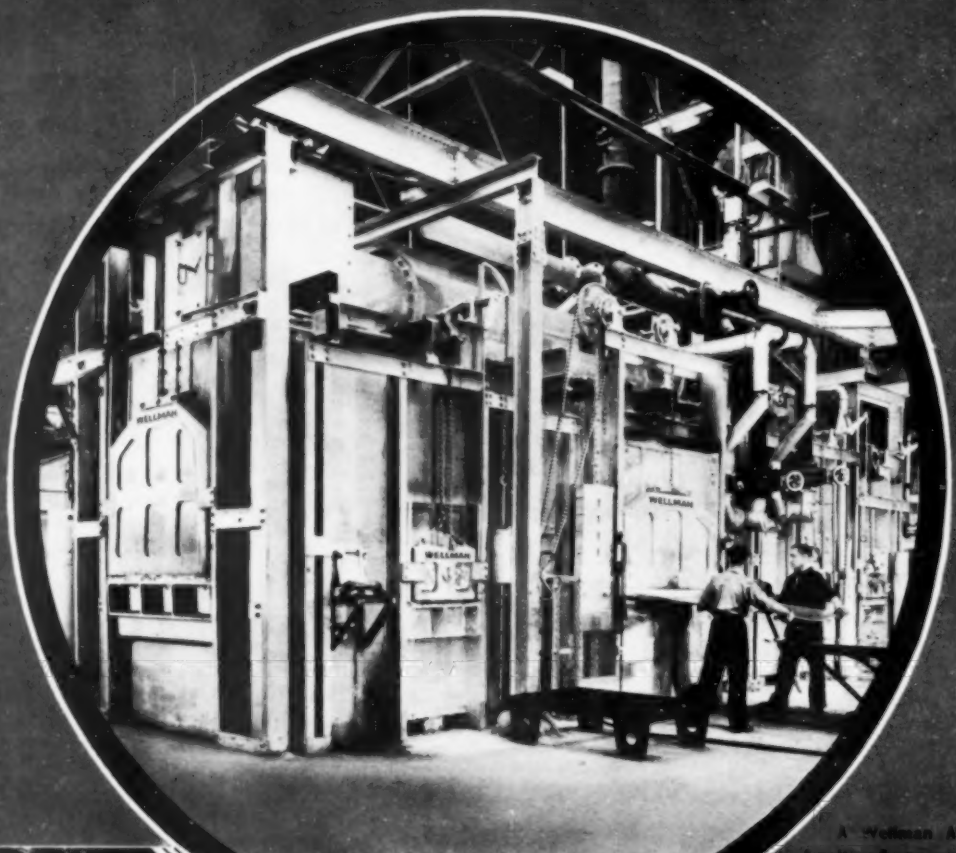
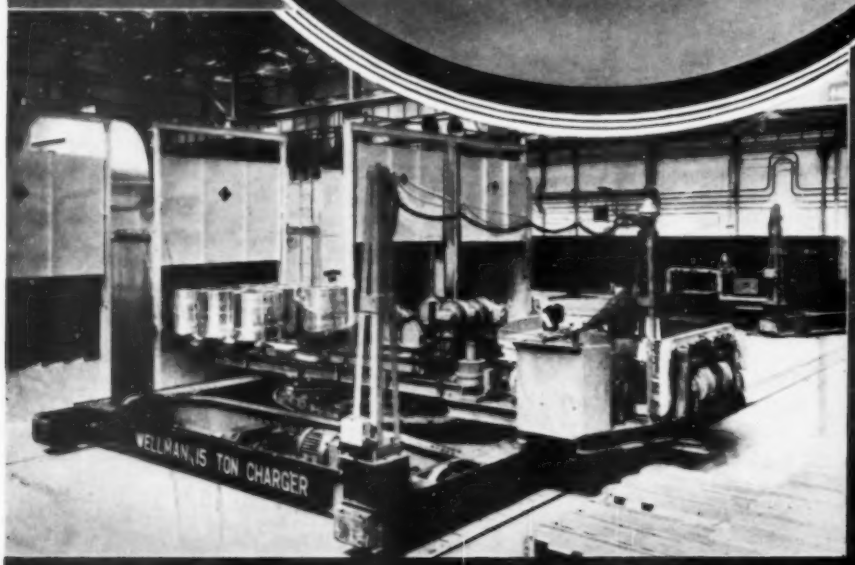
WELLMAN

Furnaces and Mechanical Handling Equipment



A Wellman Aluminium Smelting Furnace supplied to the Northern Aluminium Co. Ltd., Rogerstone.
In addition there are 19 Wellman Cranes, ranging in capacity from 5 tons to 40 tons, in operation at these Works.



Wellman 15 ton Finger Type Chargers and Turntable in service at the British Aluminium Co. Ltd., Falkirk. This installation also includes a 10,000 lbs. Wellman Slab Discharger and a 10,000 lbs. Slab Handling Crane.

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

APRIL, 1956 Vol. LIII. No. 318

The Motor Industry

IT is difficult to realise that only about fifty years ago a motor car had to be preceded by a man with a red flag, and that for a long time after that the motor car could fairly be classed as a luxury, and its manufacture as a luxury industry. The extent to which all that has changed is evidenced by the effects of the recent financial restrictions imposed by the Government, combined with a falling off in exports. Nor were the effects confined to the car manufacturing organisations: countless other firms concerned with the manufacture of components and accessories also felt the draught and had to act accordingly.

It is, therefore, of vital importance to a whole range of feeder industries to know what the future holds for the motor industry. This is particularly true of the steel industry, which has been supplying a little over 10% of its total home deliveries for the "manufacture and repair of motor vehicles, cycles and aircraft (including parts and accessories)." The weekly average for January, 1956, at 30,300 tons, is higher than for any other single industry—constructional engineering coming next with 22,000 tons—and the major part is undoubtedly taken up by the motor industry. Included in this total is almost a quarter of the steel industry's production of sheet and strip, the supply of, and demand for, which has been the cause of much concern during the post-war years. The increased demand for this class of material, for the manufacture of both cars and other consumer goods, has led to calls for the establishment of another strip mill. From the trends in the consumption of flat products, it certainly looks as though a new strip mill will be needed, but, in view of the fact that coke ovens, blast furnaces and a steel plant will be necessary to feed it, and that such a works cannot be laid down overnight, the time of commencing the constructional work is a matter for serious consideration, otherwise considerable investment capital will be tied up which could have been used for financing other schemes.

Enough has been said to emphasize the vested interest which the steel and other industries have in the motor industry. Since the war the industry has enjoyed a period of unprecedented prosperity, and for its good work in the export field it has had the approval of the nation. For the first time on record, the production of cars and vehicles exceeded one million in 1954, and expansion continued in 1955 until the output was nearly two and a half times as great as in 1937, the peak pre-war year. Is it going to continue expanding, or is output likely to stabilise at the present level? Expansion plans announced by British manufacturers would, if carried out, raise the industry's annual output to 1,500,000 vehicles by 1960—an increase of 50% on the 1954 figure. Whether a million and a half vehicles can be sold is another matter.

The rapid expansion of the motor industry since 1945 has been the result of two main factors: the leeway to be made up after the war; and the rising level of real income in many countries. If the industry continues to export something like half of its output, there will be some 750,000 vehicles a year to dispose of in the home market, and if the present levels of taxation and increases in the cost of living continue, this is by no means certain of achievement. In the export field there seems to be even greater doubt, even though lower profit margins are often taken compared with home sales. Exports to Europe, which represented one-third of total car exports and one-quarter of total commercial vehicle exports in 1954, fell absolutely, as well as relatively, in 1955 in the face of severe competition, especially from Germany, and there seem to be no good grounds for assuming a reversal of this trend. Again, the possibility of increased home production in Commonwealth countries such as Australia cannot be overlooked, and most certainly the threat of increased sales pressure in these countries by American manufacturers should not be underrated.

It is acknowledged that a good home market is essential for success in the export field, owing to the reduction in costs possible with overheads, such as tooling, spread over a larger number of vehicles. On the other hand, this is only true if the overseas customer is getting what he wants. For that reason, it is pointless to design for the home market and adopt a take-it-or-leave-it attitude towards customers abroad. From time to time we hear impassioned pleas for better roads in this country, but these are usually made in connection with traffic-carrying capacity rather than surface condition. Perhaps in some respects the surfaces are too good, for without doubt many cars sent overseas see service on roads which are very inferior to ours, and suspension systems suitable for the one may be useless for the other. Again, we prefer a four-door saloon, whereas in a number of countries the two-door type is favoured. Complaints have also been made on the grounds of finish, and if export models are no better than those sold in the home market, we can all appreciate the validity of this criticism. Whatever the factors contributing to the poor quality of the chromium plating—whether they be due to cost or shortage of materials—would it not be better to reduce the amount and improve the quality. Alternatively, is the possibility of using brightened aluminium for trim being as actively pursued as it might be?

For success in the export field in face of increasing competition, not only must the car be right, but so must its price. Large scale production is acknowledged as the biggest factor in cost reduction, and in an article in the "Manchester Guardian Survey of Industry, Trade and Finance, 1956," the suggestion is made that the best hope for reducing the number of models lies in a reduction in the number of large firms, and an increase in the scale of those that remain.

Personal News

DR. R. J. ANDERSON has resigned his position as Head of the Department of Metallurgy, Southwest Research Institute, San Antonio, Texas. He has joined the Diamond Metal Co., Inc., and associated companies, Houston, Texas, as Director of Research and Development.

MR. D. K. COUTTS has been appointed Manager of the Technical Office of The Mond Nickel Co., Ltd., in Bombay, in succession to the late MR. J. MCNEIL.

MR. W. W. WATT, who has been Managing Director of The British Oxygen Co., Ltd., since 1938, has retired on reaching the age of 65. During the period of his office, British Oxygen have expanded continuously and Mr. Watt has from time to time visited all the company's interests at home and overseas.

MR. A. E. CRAWFORD has recently joined the Brush Crystal Co., Ltd., at Hythe, Southampton, to take charge of a new research laboratory for the development and application of piezoelectric materials.

MR. N. HILLS has been appointed Chief Engineer of the Aston Chain & Hook Co., Ltd., of Erdington, Birmingham. He was formerly with James A. Jobling & Co., Ltd., and with Northern Aluminium Co., Ltd.

DR. N. P. ALLEN, Superintendent of the Metallurgy Division of the National Physical Laboratory, has been elected a Fellow of the Royal Society in recognition of his work on alloy steels, their transformations and their engineering properties.

MR. F. BONSALL, who has been General Manager for several years, has been appointed a Director of British Furnaces, Ltd., and MR. R. V. CUTTS, who was previously Technical Representative, has been appointed Technical Sales Manager.

MR. P. R. LAKE has been appointed a mining expert to Burma by the United Nations Technical Assistance Administration. While in Burma, he will assist and advise the Ministry of Mines in the development of the tin and tungsten mining industry and in the planning and designing for exploration, development and exploitation of tin and tungsten areas to be operated by the Government.

MR. T. H. WINDIBANK, C.B.E., has resigned from the Board of Crompton Parkinson, Ltd., after 33 years with the Company, of which he has been a Director for the past 17 years.

SIR BEN LOCKSPEISER, K.C.B., F.R.S., who recently retired as Secretary of the Department of Scientific and Industrial Research, has joined the Board of the Fulmer Research Institute.

MR. R. H. PHILLIPS, the Secretary and Chief Accountant, has been appointed a full Director of Armstrong Whitworth (Metal Industries), Ltd., and Jarrow Metal Industries, Ltd., with duties covering financial work, works clerical and general internal office organisation. MR. E. JARVIS has been appointed Industrial Accountant, and MR. J. LAMB Head Office Accountant of the Group. MR. C. PULLEN, Sales Director, is to assume complete charge of all commercial and sales activities and will be relieved of certain outside work by MR. T. A. BIRD, who has been appointed Sales Manager of Rolls, and MR. WALKINGTON of Foundry and Engineering Products. MR. C. LUSHLEY and MR. J. J. HALL are to continue as Commercial Managers of Armstrong Whitworth (Metal Industries), Ltd., and Jarrow Metal Industries, Ltd., respectively.

MR. L. MILLER, formerly Advertising Manager of The Loewy Engineering Co., Ltd., has been appointed Publicity Officer to British Titan Products Co., Ltd.

PROFESSOR J. F. BAKER, Professor of Mechanical Sciences, University of Cambridge, has been elected to a Fellowship of the Royal Society in recognition of his experimental and theoretical investigations of steel structures and his services to education in engineering.

MR. M. H. L. LEWIS has been appointed a Director of Crompton Parkinson, Ltd., and MR. M. PARKINSON has been appointed an Executive Director of the Company.

DR. D. GABOR, Mullard Reader in Electronics, Imperial College of Science and Technology, has been elected to a Fellowship of the Royal Society in recognition of his work on transient electric phenomena, electron microscopy, the theory of communication and the electric arc plasma.

THE UNITED NATIONS TECHNICAL ASSISTANCE ADMINISTRATION has announced the appointment of two British experts to assist the Government of Israel on problems of corrosion. They are DR. S. WERNICK and MR. R. PINNER.

DR. A. B. PIPPARD, Lecturer in Physics, University of Cambridge, has been elected to a Fellowship of the Royal Society in recognition of his work on the electrical properties of metals at radio-frequencies and his studies of the superconducting state.

Meeting Diary

1st May

Incorporated Plant Engineers, London Branch. "Repair of Cracked Castings—The Modern Method," by N. TINWELL. Royal Society of Arts, John Adam Street, Adelphi, Strand, London, W.C.2. 6.30 p.m. for 7 p.m.

1st and 2nd May

Institute of Fuel. Opening Conference of a Special Study of "Domestic Heating in the United Kingdom—Present and Future." Church House, Westminster. 10 a.m.

2nd May

Incorporated Plant Engineers, Leicester Branch. "Flexible Couplings," TWIFLEX COUPLINGS LTD., Leicester. College of Art and Technology, The Newarkes, Leicester. 6.30 p.m.

3rd May

Institute of Metal Finishing, Birmingham Branch. Process Control in Plating. "Works Instrumentation and Automatic Control," by W. F. B. BAKER; "Laboratory Instruments and Techniques," by DR. G. L. J. BAILEY. James Watt Memorial Institute, Great Charles Street, Birmingham, 3. 6.30 p.m.

Leeds Metallurgical Society. "Powder Metallurgy Applied to Mechanical Parts," by H. DAVIES, with film. Large Chemistry Lecture Theatre, The University, Leeds, 2. 7.15 p.m.

7th May

Society of Engineers. "Oil-fired Packaged Portable Boilers," by D. F. BRICE. The Geological Society, Burlington House, London, W.1. 5 p.m. for 5.30 p.m.

8th May

Incorporated Plant Engineers, Manchester Branch. "Mechanical Handling." Film introduced by H. A. COLLMAN. Engineers' Club, Albert Square, Manchester. 7.15 p.m.

New Tandem Cold Strip Mill at Ebbw Vale

Fastest Now Operating in Britain

THE new 21 in. and 53 in. × 42 in. 5-stand tandem cold strip mill built by Davy and United Engineering Co., Ltd., for Richard Thomas & Baldwins, Ltd., is now in production at Ebbw Vale. It replaces the original 5-stand mill of American manufacture which had worked continuously for 17 years from 1938, when Richard Thomas & Baldwins became the first producers in Europe of tinplate by the continuous process. In its main duty, the reduction of hot rolled steel strip down to tinplate gauges, its output will show a very considerable increase over the old installation, due to the much higher rolling speed of which it is capable.

The new 5-stand mill has been designed for a finishing speed of no less than 5,000 ft./min., which makes it the fastest cold tandem mill at present operating in Britain. The strip rolled ranges in width up to 38 in. maximum, the ingoing gauge being up to 0·140 in. maximum, while the outgoing gauge is down to 0·006 in. minimum: coils weighing up to 36,000 lb. each can be handled.

On the score of output, it is generally assumed to-day that a fast mill with a finishing speed of around 4,000/5,000 ft./min. will comfortably produce at least 8,000 tons of tinplate in a week, but a considerably higher weekly tonnage than that can be expected when this new mill works up to full production, and outputs of the order of 9,000/10,000 tons per week are regarded as well within the bounds of practical rolling possibilities.

Rolling speeds of this order obviously demand driving power of equivalent magnitude, hence the reason for the total connected horsepower of 18,250 for the new 5,000 ft./min. mill, against the 5,100 h.p. of the previous 5-stand mill, which had a top speed of only 1,500 ft./min. High speeds also demand designs of great strength in the main mill units, if freedom from vibration and consequent sustained accuracy of strip are to be achieved.

Main Design Features

The new mill uses housings produced as one-piece steel castings with post areas of 870 sq. in. As cast, each of these housings weighed over 100 tons, and in the fully finished machined state weighed 93 tons. The stands of the mill are spaced at 13 ft. centres, with the pass line established at the convenient operating height of 36 in. above mill floor level.

The 21 in. diameter alloy steel forged work rolls are carried in Timken 4-row taper roller bearings of balanced proportion type. The top work roll assemblies are balanced hydraulically from a 1,600 lb./sq. in. service, using in each case four jack rams of 4¼ in. diameter working in steel cylinders mounted in the bottom work roll chocks. The work rolls are arranged for internal water cooling should this be found desirable.

Each stand is powered by direct-coupled motors, driving through pinion stand and spindles, the latter being spring balanced in the case of the first, second and third stands, and hydraulically balanced on the fourth and fifth stands, in which the higher spindle speeds must be reckoned with. It should be noted that a high speed mill lends itself to the selection of mill motor speeds which are suitable for direct-connected application, with the result that reduction gear drives can be eliminated. This offers two advantages, namely, first, that the stand centres can be kept closer together, and second, that the motor armatures can be kept to small overall dimensions. By arranging them in single, double and treble formation the inertia values can be kept low, an important factor in view of the need to ensure quick acceleration of the mill after threading the strip. Motor ratings, powers and speeds are as set out in the table on the next page.

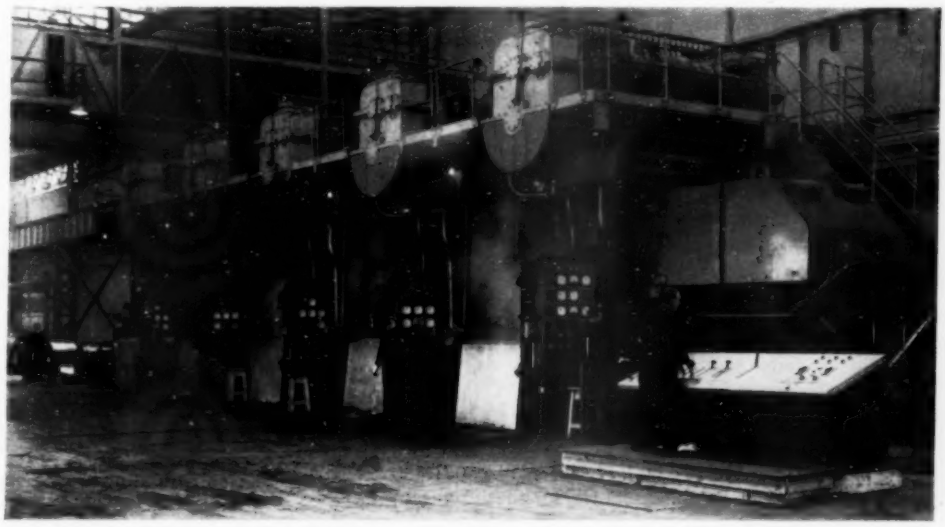

Fig. 1.—The new strip mill seen in operation.

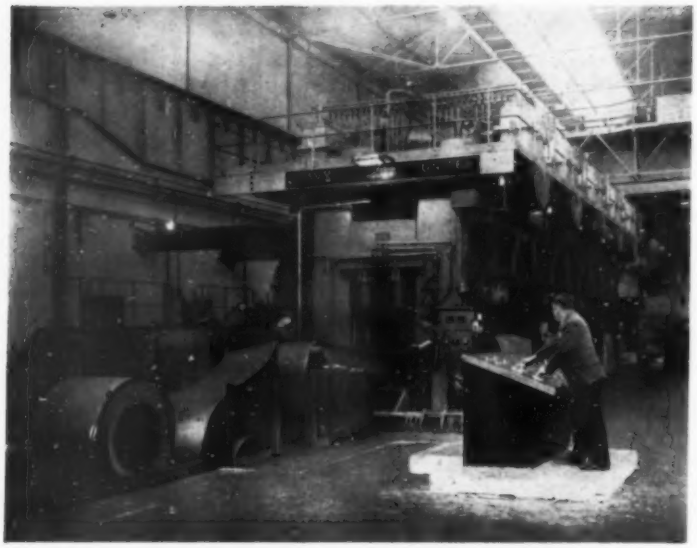

Fig. 2.—View from the entry end. The strip is being inserted into the first stand prior to being threaded through the mill.

Stand	Motor			Mill Speed (ft./min.)
	No.	h.p.	r.p.m.	
1	1	1,750	90/255	495/1,400
2	2	1,750	125/304	688/1,667
3	2	1,750	200/445	1,100/2,440
4	2	2,000	350/645	1,930/3,550
5	3	1,834	500/910	2,750/5,000

The 53 in. diameter special cast steel back-up rolls rotate in oil film bearings carried in cast steel chocks: the bearings are the well-known Morgoil type of the 42 in.—90 series. The principles of design and operation of Morgoil bearings are well established, as is their ability to sustain high rolling loads at high speeds when rolling thin gauges to fine tolerances, a fact borne out by the application of Morgoils to virtually all the present known fast mills in the world.

Back-up rolls weigh 19 tons each, and the top and bottom back-up chocks weigh 10 and 11¼ tons, respectively. Top back-up roll assemblies are hydraulically balanced from a 1,600 lb./sq. in. service, utilising four 5½ in. diameter jack rams working in steel cylinders mounted in the bottom back-up chock in each case.

Roll Changing

Whereas work rolls are changed by porter bar, the weight of the top and bottom back-up roll and chock assemblies, 42 tons in each case, calls for the application of an hydraulic system. This makes use of hydraulic jacks and a cast steel sledge, located between the bottom back-up chocks and the roll housings, on which the back-up assemblies are withdrawn from the mill. This sledge is permanently coupled to a 6 in. piston rod working in a 12 in. bore hydraulic cylinder located in an extension of the roll change pit beneath the mill floor. This cylinder has a stroke of 12 ft. and operates at 2,000 lb./sq. in.

Mill Screwdown

Screwdown gear, which is built into the roll housings, consists on each stand of two 50 h.p. motors at 550/1,650 r.p.m., coupled by a 24 in. diameter magnetic clutch, driving through double reduction gears and worm gears of 1,000 to 1 total ratio to give screwing speeds variable between 0·22 and 0·66 in./min. Selsyn units are fitted and limit switches are provided to prevent over-run. Provision is also made, in the shape of heavy cast steel make-up pieces between the 18 in. diameter mill screws and the top chocks, for the later fitting of loadmeters, should it be desired at some future date to measure the mill load electronically.

A particular feature of the screwdown gear is that the conventional involute tooth worm and wheel has been replaced in this case by a cone worm and wheel of the double enveloping type. It is claimed for the cone worm that its large instantaneous contact per tooth, plus multiple tooth contact, results in greater load carrying capacity at lower unit pressures.

Feeding, Delivery and Inter-Stand Equipment

Incoming coils are loaded by floor trucks on to a 33 ft. long power driven slat conveyor, which has a capacity of four coils of 36,000 lb. each and an operating speed of 20 ft./min. From the conveyor, coils are passed one at a time on to an entry ramp provided with a single air-operated stop by which the coil is held and then released. On release, the coil is received into a rotating rig, rotated to allow its tail to be positioned over a deflector roll mounted on the top of the following coil box, and then, by the hydraulic release of a stop plate, ejected into the coil box.

This fabricated unit is equipped with two lower support rollers and three back rollers. The coil is centralised in the box by two hydraulically controlled revolving platens which can be pre-set to suit varying coil widths by a stop and measuring device. These platens are faced with phosphor bronze and fitted with idle roller inserts to protect the edges of the coil from damage when the platens move inwards. From the deflector roll above the coil box, the tail of strip is fed

Fig. 3.—The coil building up at speed on the outgoing tension reel.

into the first stand of the mill through a heavy construction entry guide. This guide is of the swinging type, so designed in order to facilitate roll changing, and is repeated on each subsequent stand of the mill.

Between successive stands, single roll tensionmeters of special Davy-United design are fitted to allow the measurement of inter-stand strip tension. Located at the delivery sides of the third and fourth stands are double holding down rolls which work in conjunction with the tensionmeters, and which serve a dual purpose. The first function of these rolls is to steady the strip and damp out any vibration, and also to control the whip of the tail end of the coil as it leaves the preceding stand. The second function is to spread the palm oil sprayed on to the strip at these points, and to meet this requirement the roller sited nearer to the mill stand is spirally grooved to give quick rough spreading, and the following second roller is plain in surface to give even spreading.

Further inter-stand fitments include cobble-guards on the outgoing sides of stands 2, 3, 4 and 5; spray banks between all stands for applying roll coolant and palm oil to the strip; and a complete fume extraction system of Visco design, which, working through an 84 in. fan, vee rope driven from a 200 h.p. motor, removes all obnoxious fumes from the operating stations at the rate of 120,000 cu. ft./min., discharging via underground tunnel and vertical duct to an external eliminator and stack.

On its exit from the last stand, the strip can have its gauge checked by a flying micrometer located between two deflector rolls which maintain a constant passline for the strip to ensure accurate reading. The strip is then coiled on an overwinding tension reel, the intial laps being assisted by a retractable reel entry guide and a belt wrapper of the twin belt overwinding type, which is traversed up to and away from the reel by a hydraulic cylinder.

Fig. 4.—Corner of the oil cellars which cover about threequarters of an acre.

Fig. 5.—Finished coils on the delivery conveyor. The middle coil is on the weighbridge section of the conveyor, its weight being indicated on the scale seen in the left of the picture.

The tension reel itself is of the well-proved Klein type, concentrically expanding and particularly suitable for coiling very thin strip under heavy tension. The reel has a diameter of 20 in. when expanded, and is driven by a direct coupled 900 h.p. motor. At the conclusion of its build-up the coil is stripped from the reel by an hydraulically operated stripping carriage embodying stripper plate and elevator. After a sideways traverse to clear the reel, the elevator lifts and the coil is automatically ejected sideways on to a delivery conveyor via a single stop delivery ramp. The delivery conveyor is, like that on the entry side of the mill, a power driven slat conveyor of Bagshawe manufacture. It is 29 ft. 3 in. long, has a speed of 30 ft./min. and has a capacity of five 36,000 lb. coils. Built into the conveyor is an hydraulic lifting mechanism which is supported on a 6 ft. square platform forming a weighbridge. This mechanism lifts the coil clear of the conveyor and enables its weight to be recorded on an adjacent Avery scale.

Controls for Auxiliary Equipment

Two neat, streamlined, electro-hydraulic control desks, at the entry and delivery ends of the mill respectively, govern the numerous motions required for the operation of the various units of auxiliary equipment provided for the mill. The desk at the entry end includes hydraulic controls for the coil rotating rig elevator and tilting motions—the latter being remotely controlled from No. 1 stand—as well as electric controls for the entry conveyor, entry ramp stop, coil rotating rig and hydraulic pumps. The delivery desk contains all hydraulic controls connected with the motions of reel stripping, belt wrapping and coil weighing, air controls on the coil delivery ramp stop, tension reel brake and deflector plate, and the electric controls for the delivery conveyor hydraulic pumps and the sliding door to the safety cage which surrounds the belt wrapper and prevents access to the reel during coiling.

Cooling and Lubricating Systems

Just as the general tendency towards higher rolling speeds and greater coil weights calls for faster and more efficient automatic handling equipment, so the same trend towards faster operation and greater productivity demands more highly engineered and automatic systems for the supply of roll coolant, oil and grease for mechanical lubrication and palm oil for spraying on to the surface of the strip.

Lubrication engineering and the extent of oil cellar layout now required on a modern high-speed tandem strip mill are such that a full survey of all the complex equipment now necessary would probably exceed in length the description of the mill to which these services apply. In fact the large strip mill of to-day increasingly takes on one well-known characteristic of an iceberg—there is often more below surface than above it.

Recognising this trend of development, Davy-United set up some years ago their own lubrication engineering department, capable of designing and installing all the varied and complex systems now met with in this specialised brand of rolling mill work. In the case of the new 5-stand mill at Ebbw Vale, Davy-United have been responsible for all the coolant, lubrication and palm oil systems involved, even down to the many miles of interconnected piping and associated fittings.

In the continuous rolling of tinplate, palm oil has been established for many years as the most suitable rolling oil for use down to the very light gauges. This is attributable both to the chemical composition of the oil and its high load-carrying capacity at extreme local temperatures, such as those developed in the small contact area between the roll and the strip when the metal is undergoing reduction.

Palm oil, however, is a solution which brings problems as well as advantages to the mill designer and operator. Since it solidifies at around 95° F. all the palm oil tanks must be steam heated, and it is also necessary to run steam tracers alongside the piping carrying the palm oil in order to keep it in liquid form.

To summarise briefly the centralised systems provided on the new 5-stand tandem mill at Ebbw Vale, the following equipment may be listed :—

250 gal./min. Morgoil bearing oil system, serving stands 3, 4 and 5.

75 gal./min. Morgoil bearing oil system, serving stands 1 and 2.

140 gal./min. gear oil system, serving mill pinions and screwdown gears.

10 gal./min. spindle bearing system, serving bearings on all mill spindles.

17 gal./min. palm oil system, feeding to the mill by a ring main and controlled at each mill stand by a patented atomiser.

4,000 gal./min. roll coolant system.

Palm oil and roll coolant reclamation systems, in which circulated palm oil is separated out from the coolant prior to treatment and re-circulation.

Two Farval systems for automatic grease lubrication, serving all grease points in the mill.

Hydraulic supply systems for all auxiliary operations so motivated. With the exception of the roll balance which is fed from a weight loaded accumulator, these operate from direct pump supply.

Conclusion

There is no doubt that this new mill has a significant part to play in the steel industry's drive towards still greater potential for the supply of flat rolled steel and, in particular, tinplate, of which the current British output still falls considerably short of the combined home and export demand. The installation of this new 5-stand tandem mill, with its designed finishing speed of 5,000 ft./min., marks another notable stage in the record of rolling by the continuous process in this country, a record which is stamped at every turn by the kind of close co-operation between steel producer and mill builder which has brought this mill into being.

British Titanium World's Cheapest

With the announcement in February of a reduction in price to about 21s. (below $3)/lb., I.C.I. raw titanium became the cheapest in the world, the current price in the U.S.A. being $3.45/lb. Only ten or twelve companies have so far entered the field of raw titanium production on a large scale, and there has been keen competition between them to improve extraction techniques so as to cheapen their product, which is the raw material for the producers of wrought titanium products for industry. In consequence, from a price of $5/lb. at the beginning of 1954, the price of first-grade titanium has dropped in five successive reductions to $3.45/lb.

In August, 1953, Imperial Chemical Industries, Ltd., announced that they were going to build a plant to produce 1,500 tons of titanium a year by a new sodium process of their own development. The plant came into operation in 1955, less than two years after planning was started. I.C.I.'s titanium has important advantages in its physical form. Instead of the coke-like " sponge " of the conventional Kroll process, the titanium is in the form of small granules which can be pelleted with alloying materials into a form ideal for melting.

Heliarc Equipment

Quasi-Arc, Ltd., of Bilston, Staffordshire, announce that they are now sole licensees in this country and the Commonwealth for the Heliarc welding equipment described below.

The Heliarc spot welder makes tungsten-arc argon-shielded spot welds in stainless steels, low alloy steels and mild steels. Since the welding is from one side only, spot welds can be made in places inaccessible to resistance welders.

The HWM-1 Heliarc welder is a semi-automatic tungsten-arc machine which is designed for high speed welding of thin materials, and is particularly adaptable for contour welding. A wire guide attachment is fastened directly to the torch handle, and a trigger, controlling feed of wire from the reel, is located in the torch ; thus the filler wire is invariably positioned correctly in relation to the arc, and operation of the torch is simplified so that the operator merely guides the torch along the joint, as the torch is driven by the force of the filler wire speed.

The Heliarc HWM-2 welder is a controlled-arc machine designed for automatic welding : it maintains a constant arc voltage and hence a constant arc length throughout the welding cycle. Movement of the torch is controlled over a range of 14 in. The control operates on a proportional principle, i.e., the speed of direction is proportioned to the error in the voltage ; thus if the error is large the torch moves rapidly to correct it and if the error is small, the torch moves more slowly. By this consistent welds over irregular surfaces are possible. With the torch mounted on an OM.48 side beam carriage, welding speeds up to 200 in./min. are obtainable.

Copper and Copper Alloys

A Survey of Technical Progress During 1955

By E. Voce, Ph.D., M.Sc., F.I.M.

Copper Development Association

Continued progress has been made in the past year in the metallurgy of copper and its alloys, and in the various sections of this review the author discusses the principal items of interest concerning such aspects as raw material resources, extraction, fabrication, finishing and properties.

(*continued from page* 107 *of the March issue*)

Finishing and Plating

SEVERAL important conferences on metal finishing were held during last year, notably those of the Institute of Metals, the Institute of Metal Finishing, and the American Electroplaters' Society. Papers relevant to the present survey are reviewed, with others, under the appropriate classified headings below.

Mechanical Finishing and Heat Treatment

The Spring Symposium of the Institute of Metals dealt last year with finishing operations and heat treatment. Two papers of vital interest to the copper industry were included, namely, those of Hysel and Collier[89] on the copper-base alloys in general, and of Miller[90] on copper and aluminium rod and wire. Both are packed with detailed information concerning modern practice in the final stages of production. Hysel and Collier[89] describe a number of specialised heat treatment processes, such as those required for the removal of internal stress and for the development of optimum properties in precipitation-hardening alloys like chromium-copper. They also outline the precautions desirable in mechanical finishing operations such as shearing, straightening, cutting to length, and the removal of burrs, while a section is devoted to the avoidance of damage during warehousing and delivery. Miller[90] is concerned largely with the surface quality of copper wire, and the factors by which it is influenced. He reviews the testing of copper wire with special reference to springiness, a property which is of great importance in the winding of coils for electrical apparatus.

An "advanced" method of barrel finishing of metal components, developed in Sweden, has been described by Arensten.[91] It differs from the old tumbling process in that the parts under treatment do not touch each other, but are continuously embedded in a specially prepared medium.

Electrolytic and Chemical Polishing

A report on Western German practice by Pinner[92] states that "there has been an intensive drive to develop both electrolytic and chemical polishing processes." An electrolytic process employing a solution of phosphoric acid in a mixture of alcohols is being used for polishing small brass parts, and is said to produce a finish as good as any seen by the writer of the report. Chemical polishing of brass and nickel silver using phosphoric-nitric-acetic acid mixtures has also been studied, and it has been found that the finish can be improved by part replacement of phosphoric acid with arsenious acid. Baur,[93] also in Germany, has provided a detailed compilation of patent specifications, published in various countries, relating to the electrolytic and chemical polishing of copper and copper alloys and other metals.

Electrodeposition of Copper

Nevers, Hungerford and Palmer[94] have emphasised that the addition of 0·02–0·03% of phosphorus to copper anodes for plating from acid sulphate baths improves the overall efficiency. Safrenek and Faust[95] have also studied the influence of copper anode composition on the degree of sludge formation in cyanide and acid sulphate baths.

The practical advantages of periodic reverse current plating are illustrated by a statement[96] to the effect that the time required to produce a certain thickness of deposit from a standard high speed potassium-copper cyanide solution was thereby reduced from 5 hours to 3 hours. A modification of the periodic reverse current process, in which the current density of the anode pulse is made lower than that of the cathode pulse, has been proposed by Schmidt and Springer[97]. In his review of electroplating practice in Western Germany referred to above, Pinner[92] says that the periodic reverse current method for copper electrodeposition has been widely used in that country. He also mentions that one of the most interesting bright copper processes in Germany is the new "Cupat" solution, which employs a sulphate bath and a number of addition agents; an unusual feature is that the solution will give adherent deposits directly on steel after a sulphuric acid dip containing an undisclosed addition.

Rama Char and Shivaraman[98] have shown that smooth, bright and adherent copper deposits can be obtained on steel from complex triethanolamine baths, and Dickinson[99] has given particulars of an American process, now operated in this country, for the electrodeposition of copper and brass from pyrophosphate solutions. Izmaylov and Gorbachev[100] have discussed the throwing power of various complex copper electrolytes, while Shreir and Smith[101] have classified addition agents to copper sulphate baths according to their effect on the cathode polarisation potential and the structure of the deposit.

Two papers have been published on the influence of ultrasonic waves on the electrodeposition of copper.

Wolfe, Chessing, Yeager and Hovorka[102] examined the effect of these vibrations on copper deposited from acid sulphate baths, and reported a marked decrease in polarisation with an increased tendency towards preferred orientation in the deposit. Rich[103] also found that ultrasonics greatly reduced anode polarisation in cyanide copper baths, and that the upper limit of current density was increased.

Electrodeposition of Copper Alloys

The electrodeposition of copper-base alloys has been steadily increasing in industrial importance during the past few years. A group of large organisations who have jointly been examining substitutes for nickel as an undercoat for chromium plate on steel, has reached the conclusion that an electrodeposited bronze containing between 10 and 12% tin represents optimum practice.[104] Safranek and Faust[105] describe a technique of bronze plating, using a bath containing copper cyanide and stannous pyrophosphate with cast anodes of a copper-tin alloy, and Lowenheim[106] that of depositing 10%-tin bronze from an alkaline cyanide solution.

Experiments have led to the development of a method of high-speed brass plating, especially for buffed coatings.[107] Details have been given of a patented process used in America for the continuous brass plating of steel strip,[108] and a modified technique for the deposition of high-zinc brasses from cyanide baths containing a soluble dithiocarbamate has also been patented.[109]

Electro-Tinning of Copper Wire

Two papers on the electro-tinning of copper wire merit attention, namely, those of Cuthbertson,[110] who refers to multistrand units using stannate baths, and of Carlson,[111] who claims advantages for the stannous fluoborate type of bath.

Other Coating Processes

According to West,[112] the deposition of nickel, without electrolysis, on copper and copper alloys can be achieved from an ammoniacal solution of nickel chloride containing sodium citrate and sodium hypophosphate. Culverhouse[113] has patented a method of coating aluminium with copper by immersion in a solution of alkali zincate, to deposit a film of zinc, followed by transfer to an acid solution of copper fluoborate, which removes the zinc and replaces it by an adherent layer of copper.

An interesting method of producing an adherent black coating on copper, brass, aluminium bronze and tin bronze has been developed by Clarke and Andrew,[114] by electrolytic anodising in a solution of hot 15% caustic soda containing sodium or ammonium molybdate. The process has been utilised as a substitute for platinum black for the blackening of optical instruments.

Electroforming

The technique of electroforming is becoming widely used for the production of microwave equipment, and three publications provide detailed information on the process for this class of work. Walker, Bentley and Hall[115] describe the care which must be taken in the preparation of the mandrels. A cyanide copper bath with periodic reverse current plating was employed, which provided deposits freer from stress than when normal D.C. plating was used. The second paper[116] describes the manufacture of electroformed waveguides in a works specialising in their production, and the third[117] is similar in scope, emphasising the very precise limits of dimensional accuracy to which the components can be made.

Properties and Applications

Copper and Copper-Rich Alloys

A recent literature survey[118] summarises creep and stress rupture data for tough pitch and phosphorus-deoxidised copper, and includes references relating to copper with small alloying additions of silver, arsenic, manganese, cadmium and chromium. The creep of copper with other small additions has been investigated by Martin and Smith[119]; with copper containing 0·05% aluminium, they report a considerable improvement in creep resistance after internal oxidation, while the creep resistance of internally oxidised single crystals of a copper–0·3% silicon alloy was found to depend on the degree of dispersion of the oxide.

The effects of strain rate and temperature on the compression of phosphorus-deoxidised non-arsenical copper, among other metals, have been studied by Alder and Phillips.[120] A useful table of data is given covering temperatures from 18 to 900° C., with strain rates up to 40 true (logarithmic) strain units per second.

Aluminium Bronze

Several interesting publications have appeared concerning the aluminium bronzes, notably that of McKeown, Mends, Bale and Michael.[121] These authors studied the creep and fatigue properties of a series of complex alloys containing 5% each of iron and nickel, with aluminium contents up to 11·6%. The tests showed that the alloys with between 3 and 7% aluminium had the best creep properties, but the best combination of creep properties with ease of forging was given by alloys containing 9–9·75% aluminium. Corrosion fatigue tests in salt solution gave results superior to those on comparable samples of stainless steel and stainless iron.

A paper by Dennison[122] describes creep, creep-rupture and tensile tests at 300° C. on six precipitation-hardening alloys based on the *alpha* copper-aluminium phase; it was found that the alloys containing small amounts of cobalt, iron and nickel exhibited discontinuous grain-boundary precipitation at normal ageing temperatures, resulting in a reduction in creep ductility, while the alloys containing small additions of titanium or zirconium exhibited high ductility at all strain rates.

The use of an *alpha* precipitation-hardening aluminium bronze for high pressure hydraulic piping in aircraft has been advocated by Ashton and Wilson,[123] who also discuss, with accompanying mechanical property data, other specialised applications of aluminium bronze alloys, viz., gas turbine compressor blading, and press tools and deep drawing dies for components made from stainless steel and other metals. Vanick[124] emphasises the merits of aluminium bronze containing nickel as a propeller alloy, and aluminium bronze propellers are reported to have given exceptionally good resistance to cavitation and erosion after a year's continuous service.[125] A type of aluminium bronze said to be specially suitable for marine propellers has been patented in this country.[126] It contains about 12% manganese in addition to 7·5% aluminium, with several per cent. each of iron and nickel.

Ramachandran and Iyer[127] have studied the eutectoid transformation of *beta* aluminium bronze, while Nishimura, Adachie and Aoki[128] have examined precipitation hardening effects in *alpha* aluminium bronzes containing tin.

Alloys Containing Tin

The mechanical properties of sand cast tin bronzes have been studied in two papers by Le Thomas. In the first,[129] he found that with a phosphorus content of 0·07% or less, the tensile strength decreased as the amount of *alpha* + *delta* eutectoid became greater, while with 0·17% or more of phosphorus, the tensile strength increased with the proportion of eutectoid. In his second paper,[130] Le Thomas surveys the effects of other elements including iron, nickel, manganese, aluminium, sulphur, phosphorus, antimony, arsenic and silicon on the structure and mechanical properties of sand-cast tin bronzes. Edwards[131] has examined the elevated-temperature properties of cast and aged nickel gunmetals, with and without additions of lead, and suggests that these materials may be suitable for valve and pump trim applications.

The development of some interesting new copper-base alloys has been reviewed by Ellwood,[132] who discusses the effect of adding tin to beryllium-copper, the addition of manganese to tin bronzes, and the merits of tin as an alloying element in cupro-nickel. It is claimed that the presence of about 10% of tin in beryllium-copper reduces the amount of beryllium needed to achieve good precipitation-hardening properties from 2% to about 0·5–0·75%. Of the copper-tin-manganese alloys, which have been developed to replace cupro-nickel for deep drawing purposes, the composition containing 16% manganese and 6% tin was found to have optimum properties, and to be similar in colour to a "white" cupro-nickel of high nickel content. The third group of alloys, cupro-nickels containing tin, are proposed for stamping and coining operations, and the presence of 3–5% of tin is said to permit the use of a nickel content of 15% instead of the more usual figure of 25%.

Beryllium-Copper

In addition to the copper-tin-beryllium alloy just mentioned,[132] a modified type of beryllium-copper containing a considerable assortment of added elements has been developed.[133] The beryllium content of this alloy is also appreciably less than that of the normal commercial material, over which it is claimed to have advantages in respect of improved cold working properties and insensitivity to over-ageing.

In view of the increasing use which is being made of beryllium-copper moulds for plastics, a recent paper[134] on this particular application will undoubtedly prove of interest. The merits of such moulds are outlined and the methods of producing them are described; the molten alloy is generally poured round a master hob and pressure applied as the metal solidifies, although investment casting or sand casting methods can be employed. A second article on beryllium-copper moulds, by Sanders[135] describes their use as dies for zinc-base die castings.

Chromium-Copper

Köster and Knorr,[136] in one of the most detailed investigations yet made on the age-hardening characteristics of wrought chromium-copper, have demonstrated by means of numerous graphs the response of a 0·6% chromium alloy to heat treatment at 20–700° C. for periods up to several months; their results cover the changes which occur in both physical and mechanical properties under these conditions of ageing.

Gruhl and Fischer[137] have extended the work to cover the effects of equally prolonged heat treatment on similar material in the cold worked condition. Hibbard and Hart[138] have found the strain-hardening characteristics of heat treated chromium-copper to be dependent upon the amount of precipitate present.

Other Copper Alloys

Dies[139] describes comprehensive experiments on the heat treatment and properties of the commercial copper-nickel-silicon alloys, while Dreyer[140] has shown that copper-cobalt-manganese alloys have greater hardenability and higher recrystallisation temperatures than are conferred on copper by separate additions of these two elements.

Up to the present, the addition of copper to titanium has not attracted much attention. Holden, Watts, Ogden and Jaffee[141] have, however, shown that improved mechanical properties can be obtained by quenching hypoeutectoid alloys from the *beta* field to give a martensitic structure.

Work with a practical bias is that of Brandt[142] on the effects of internal stress in leaded brass blanks for clock- and watch-making, and of Pirner[143] on the production of brass free from magnetic properties for instrument manufacture. Hooper and Inglis[144] have recorded data on the properties of non-ferrous metals and alloys for the chemical engineer.

Corrosion

Atmospheric Corrosion

The American Society for Metals has published two important papers on the atmospheric corrosion of copper and copper alloys, respectively, after twenty years exposure in industrial, marine and rural locations. The paper on copper is by Thompson, Tracy and Freeman[145] and records data obtained on eleven brands of copper. They found that the purest copper corroded least and the arsenical varieties most, though the differences were not of practical significance. Tracy[146] details the behaviour of various copper alloys, including bronzes, brasses and cupro-nickels. In general, the alloys of lower copper content suffered the greatest corrosion, particularly the high tensile brass, though this disparity virtually disappeared in rural areas, where the rate of attack was, for all materials, the least.

A paper by Ambler and Bain[147] records the results of a large number of tests in Nigeria on steels, aluminium and a 63/37 brass. They investigated the effect of salinity and humidity on corrosion and found that, in the absence of air-borne salt close to the sea, the high humidities experienced in the tropics do not result in a greater degree of corrosion than occurs in rural areas of Britain.

Galvanic corrosion under conditions of natural exposure has been reported on by Cole[148] and by Compton, Mendizza and Bradley.[149] The papers give detailed information on the potential differences of numerous metallic couples, which include steels, copper, copper alloys and light alloys. Cole is concerned primarily with tropical environments, both inland and marine, while the other authors also include industrial exposures.

Chatterjee[150] has demonstrated the protective influences of aluminium and manganese on the resistance of copper-base alloys to atmospheric corrosion, while, to

emphasise the beneficial effect of copper on the resistance of steel to weather conditions, Tice[151] describes a fence of barbed wire containing 0·35% of copper which is still good after 75 years' exposure.

The behaviours of various metals when exposed to steam, smoke and funnel blast is the subject of an article by Marshall and Sinclair[152]. They concluded that copper has a reasonably low and even corrosion rate.

Stress Corrosion and Dezincification

Perryman[153, 154] has been responsible for two publications on the intercrystalline cracking of *beta* brasses, particularly those containing aluminium. The first of these deals with the factors which lead to intercrystalline cracking. Factors, such as the presence of aluminium, which stiffen the grains themselves, and so favour the localisation of strain at the boundaries, tend to increase the risk of intercrystalline cracking. The second paper[154] is based on the assumption that the presence of atoms of elements with high melting points would be likely to increase the effective viscosity of the grain boundaries, and so improve their resistance to rupture. Atoms of unfavourable size factor, such as those of zirconium or titanium, would tend to concentrate at the grain boundaries, and it was found that small additions of these elements were, in fact, moderately beneficial.

Aebi[155] has investigated the stress corrosion of ring specimens of *alpha* brass in ammonia vapour, and he reports that specimens which had been heat treated for four hours at 300° C. had a shorter life than the untreated rings. He ascribes this to the formation of dislocations at the grain boundaries, offering additional opportunities for intercrystalline attack. The addition of about 1% silicon to diminish the stress corrosion of brasses containing upwards of 76% copper has been advocated by Steinle.[156]

Also concerned with the corrosion of brasses is the work of Lombardi[157] on the factors which govern dezincification. The effects of additions of arsenic, antimony and phosphorus in amounts somewhat greater than those normally advocated, were investigated. A brief review of dezincification, with special reference to marine engineering, has been prepared by Kenworthy and O'Driscoll[158].

Aqueous Corrosion

The use of non-ferrous metals in domestic water supplies has been dealt with in a paper by Campbell[159], who discusses *inter alia* copper pipes, ball floats, and copper alloy fittings. Sobelev[160] has described an investigation on the failures of ball valves in which the predominant feature is the failure of the seating by cavitation and not by corrosion. A new experimental valve has been examined which is an improvement on existing types.

Two papers by Lancaster[161, 162] give the results of his work on the action of water under pressure at 260° C. on a number of materials, which were subjected to stress and to variable water velocities. He concludes that cupronickel (the only copper alloy studied) is not very suitable for use under these conditions.

Bomberger, Beck and Fontana[163] have published the results of their studies on the polarisation of copper, nickel, and some of their alloys in 3% sodium chloride solution. They correlate their data with that of other investigators. Polarisation studies have also been made by Rosenfel'd and Pavlutskaya,[164] who state their view that when copper is covered only by a very thin layer of electrolyte it is more easily polarised, both anodically and cathodically, than when a large volume of electrolyte is used. They discuss the bearing this may have on the ordinary atmospheric corrosion of copper.

Getty, McCready and Stericker[165] have examined the use of silicates as corrosion inhibitors in synthetic detergent mixtures. They could detect no appreciable attack on copper, brass or nickel silvers.

Chemical and General Engineering.

Cupro-nickels containing 10–30% of nickel have long been recognised as being of outstanding merit for the tubing of marine and other condensers. Their applications are rapidly broadening to include heat exchangers operating in many other types of liquid, and, with this in mind, LaQue[166] has published information on their resistance to a variety of industrial solutions. The paper includes 13 tables summarising the results of practical experience under a wide range of conditions.

Though concerned largely with ferrous materials, a paper by Groth and Hafsten[167] on the corrosion of oil refinery equipment in sulphuric acid and sulphuric acid sludges, describes experience with pumps, valves and piping in bronzes and other copper alloys. The authors disfavour the use of leaded bronzes and gunmetals under such conditions, because of the possibility of galvanic action between the lead particles and the matrix, and also because of the difficulties of welding materials containing a lead-rich phase of low melting point. A general account of corrosion in the petroleum industry, by Garner and Hale,[168] gives information on the use of copper-base alloys, especially those rich in nickel.

Todhunter,[169] writing from experience in a power station, has discussed the selection of suitable materials for condenser tubes, and has considered not only the corrosion resistance but also the economics of the selection.

An elaborate series of experiments by Caney[170] on the resistance of aluminium bronzes to boiling 10% sulphuric acid and 2·5% hydrochloric acid has resulted in a patent[171] covering alloys containing 9·5–9·7% aluminium, 1·7–2·4% nickel, and iron up to 1·0%, the balance being copper. The material should preferably be quenched from 600–650° C., to avoid the presence of the $gamma_2$ phase. Recent experience certainly suggests that the absence of the $gamma_2$ phase would be likely to improve the resistance to corrosion of aluminium bronze. Moreover, it is desirable that the distribution of the *beta* phase, if present, should be discontinuous. A type of heat treatment advocated by Schussler[172] as a precaution against stress corrosion cracking in aluminium bronze would meet the last-named requirement, but would encourage the formation of $gamma_2$ and should, therefore, be regarded with caution.

Fluorine, either liquid or gaseous, has a negligible penetration rate with low leaded brass, which was tested along with other metals by Gundzik and Feiler.[173] The reaction of fluorine with copper powders has been described by Haendler.[174] At 500° C. sufficient heat is developed to fuse the reaction mixture and volatilise some of the product. Copper is suitable for handling anhydrous hydrofluoric acid as long as sulphur dioxide and oxygen are absent.[175]

Oxidation and Scaling

Spinedi[176] has carried out experiments on the high temperature oxidation of copper-aluminium alloys con-

taining 0·2–20% aluminium. He found that the oxidation rate was at a minimum with 9% aluminium.

Frederick and Eden[177] have discussed the problem of the corrosion caused by vanadium oxide in gas turbine equipment. Tests on a 7% aluminium bronze of the type used in tubular heat exchangers showed no attack after 300 hours at 400° C., though corrosion became severe after 100 hours at 500° C.

Continuing their gravimetric investigations of metallic oxidation at elevated temperatures, Collari and Spinedi[178] have studied the alloys of copper and zinc. They give a series of curves showing the ratio of the oxidation of each alloy to that of pure copper as functions of zinc content and time at temperatures from 500 to 800° C.

Up to the present, the anodic oxidation of copper and copper alloys in aqueous electrolytes has attracted comparatively little attention, although it has been used commercially to a limited extent. Clarke and Andrew[179] have shown that such oxidation can be effected in hot alkaline solutions.

Anti-Fouling Paint

A recent note[180] refers to a patent[181] now some years old, according to which graphite milled into the surface of copper powder improves its performance in anti-fouling paints. The graphite gives rise to local galvanic couples which increase the leaching rate of the copper. The mechanism is, indeed, comparable with that by which carbonaceous films in the interior of copper tubes may lead to pitting in certain types of water.

Joining

Surveys of Literature

The doyen of reviewers of the literature on joining of copper and its alloys, Hook, has come forward once more with a thoroughly useful account[182] covering the period from 1936 to 1954. By comparison, the reprinted lecture on the same subject by Cresswell[183] makes rather dull reading.

Gas Shielded Arc Welding and Cutting

There is little doubt that the paper by Moore and Taylor[184] on metal-arc welding with argon or nitrogen shields marks another step forward in the development of this method of assembly for copper and copper alloys. While one can agree with the authors' conclusion "that the process offers marked attractions over the fusion welding methods and warrants full commercial exploitation" much research remains to be done, particularly as far as the joining of light gauge material and of high conductivity copper is concerned. A paper by Babcock[185] records further progress in applying the inert-gas-shielded metal-arc to the cutting of non-ferrous metals, including copper and copper alloys.

Pressure Welding

Some investigations on the pressure welding of copper to aluminium have been carried out by Storchheim,[186] who has merely described the results of his experiments without coming to clear-cut conclusions. Carlson and Leedy,[187] on the other hand, who have studied joints of copper flash-welded to aluminium, make definite recommendations as to how the temperature and heating period must be limited in order to avoid the growth of a brittle intermetallic compound layer. According to a brief note,[188] cold pressure welding can be satisfactorily applied to the butt joining of copper wire.

Brazing

As the result of a series of tests on tough pitch and deoxidised coppers brazed with a number of different filler metals, Munse and Crawford[189] conclude that all the filler metals in question, which embraced silver solders and copper-phosphorus alloys, had strengths greater than that of the base metal. At 200° C., the shear strength of brazed joints in general falls to little more than half the comparable strength at room temperature. This statement applies to short-time loading and does not take creep into consideration. At 190° C., the strength of brazed joints varied greatly with the nature of the filler metal, but the alloys containing silver gave, in general, better results than those containing phosphorus.

Two other articles relating to brazing might also be mentioned. In one,[190] a faster method of attaching railbonds is described, while in the other the formation and physical properties of metallurgical phases of the silver-cadmium-copper-zinc quaternary silver soldering alloys have been investigated and discussed.[191] A new American brazing manual[192] has appeared; it contains valuable information.

Powder Metallurgy

General

An important addition to the literature on powder metallurgy last year was the O.E.E.C. report.[193] It is a critical account of American practice which, apart from data on properties and methods of manufacture of sintered products, contains sections on presses and tools, furnaces, standards and quality control, and much other valuable information. Seven tables listing the general characteristics of brass powder are included.

Of the fifty papers comprising the Iron and Steel Institute's Symposium on Powder Metallurgy in 1954, as many as half are concerned with or applicable to copper, while four deal specifically with copper or copper alloys.[194-197] Of particular interest is the fact that Dunmore and Smith[195] report the fatigue properties of sintered copper to be similar to those of the wrought materials.

Rolling of Metal Powders

Developments in connection with the powder metallurgy of copper centre round the bulk production of copper powder at economical costs and its fabrication into wrought products by continuous methods. The production of copper powder from scrap by the Chemetals process of ammoniacal leaching and gaseous precipitation under pressure is already in operation on a commercial scale.[198] Rolling seems at present to be the favoured method of continuous compacting, and Franssen, who has done much to develop the technique in Germany, has published descriptions of the apparatus used.[199, 200] A recent patent by Naeser[201] on the subject may be mentioned, while American practice has also been outlined,[202, 203] and a brief but useful survey has been published by Evans and Smith.[204]

Infiltration of Porous Iron Compacts

The infiltration of porous iron compacts with copper is gaining industrial importance for the production of miscellaneous engineering parts, such as gears and

cams,[205] and several patents on the subject have appeared.[206-208] According to one of these,[208] the process of infiltration can be improved by electroplating the porous iron with copper and, after adequate washing and drying, heating to melt the copper. It is claimed that this technique ensures uniform impregnation without erosion and channelling of the compact. Another of the patents[207] covers the manufacture of commutator segments by the infiltration of porous iron with a metal of high conductivity, such as copper or silver.

Hot Pressing of Copper Powder

Palme[209] states that hot pressings from copper powder are harder than similar articles made by normal methods, even those involving cold work, and that such hot pressings remain hard at temperatures up to 300° or 350° C.

Copper Alloys

The sintering of brass has been reviewed by Corsini[210], and Bradley[211] describes the physical and mechanical properties of brass compacts. Langhammer and Glick[212] give design data for porous bronze bearings, and steel-backed sintered copper alloy bearings are the subject of recent patents.[213] The structure, properties and applications of sintered filters, including 90/10 copper-tin and 65/12/23 copper-nickel-zinc have been discussed by Frehn[214].

Physical Metallurgy

Constitution and Structure

Further investigations into the eutectoid reaction in aluminium bronzes have been made by Thomas and West,[215] who found the eutectoid point to be 565·5° C at 11·80 wt.-% aluminium. The same authors[216] have made observations on the changes in constitution of aluminium bronzes below the eutectoid temperature, and have found some evidence of the existence of an additional stable phase.

Garwood[217] has followed the steps which occur during the precipitation of the *alpha* phase from quenched *beta* brass containing 41·3% of zinc. The process was found to be comparable with that by which bainite is formed in carbon steels.

An investigation of the copper-antimony system has been carried out by Schubert and Ilschner[218] who tentatively suggest the phase boundaries. The constitution of part of the copper-lead-oxygen system has been investigated by Gebhardt and Obrowski,[219] who relate their results to previous data on the binary systems Cu-Cu_2O, Cu-Pb and Pb-PbO, which they also review. Further work on the copper-tin-phosphorus system has been performed by Muromachi, Watanabe and Tomimoto,[220] using alloys containing up to 28% tin and 12% phosphorus.

Other studies of constitution include those of Nagasaki[221] on copper-silicon alloys, of Rhines, Bond and Runnel[222] on copper-gold, and of Klochko[223] on copper-palladium alloys. The copper-palladium system has also been investigated by Sawatzky and Jaumot,[224] who showed that some modification of the equilibrium diagram is necessary.

The mechanism of recrystallisation of copper has been examined by Gordon[225] using micro-calorimetric methods, supplemented by metallographic, micro-hardness and X-ray measurements; he found that the energy of deformation is released in two overlapping stages, the first corresponding to recovery, the second to recrystallisation.

Diffusion

Using a radioactive isotope of nickel, the diffusion of nickel into copper has been studied by Yukawa and Sinnott,[226] who found that the diffusion coefficient at the grain boundaries was about 10^4 times that in the lattice. A contribution to the theory of the mechanism of diffusion is made by Resnick and Bulluffi[227] as a result of work on the diffusion of zinc and copper in *alpha* and *beta* brasses. In a comparably theoretical investigation, Horne and Mehl[228] have determined the diffusion coefficients for both copper and zinc in *alpha* brass as functions of concentration and temperature.

Oxidation

A comprehensive bibliography on the high temperature oxidation of metals has been compiled by the Department of Metallurgy of Utah University;[229] it covers 669 pages and references up to 1952.

Physical Properties

Publications have appeared on the conductivity of metals, including copper, at low and elevated temperatures. One of these, by Powell and Blanpied,[230] comprises a useful survey of the literature on thermal conductivity from 1900 to 1954, while in another, Powell[231] has collected data from many sources for numerous metals and alloys, supplementing the information from the literature with some recent tests. Powell and Coffin[232] have studied the thermal conductivity of free-machining copper containing 1% lead, while similar determinations on beryllium-copper and brass at temperatures between −271° C. and −183° C. are covered in a paper by Berman, Foster and Rosenberg.[233] White[234] records measurement of the thermal and electrical conductivities of copper from room temperature downwards to 1·4° K. The effects of impurities and also of cold work were investigated. Nicol and Tseng[235] give figures for the thermal conductivity of high purity copper at between 0·25° and 4·2° K., while the work of Rosenberg[236] covers a wider range of materials including copper. Shibuya[237] has studied the electrical resistance of the whole range of copper-nickel alloys at temperatures down to 77° K. Experiments by Darmois[238] on the electrical resistance of tin bronzes at higher temperatures are claimed to indicate the existence of an intermetallic compound, Cu_4Sn, which corresponds approximately with the *delta* phase of the equilibrium diagram. The coefficients of thermal expansion of copper from 15° to 300° K. have been measured by Rubin, Altman and Johnston[239] using both polycrystalline and single crystal copper.

The magnetic properties of copper as well as some of its alloys, including brass, cupro-nickel, nickel silver, tin bronze and aluminium bronze, have been comprehensively reviewed,[240] with special emphasis on the influence of the iron content of the materials. McClelland[241] has shown that cold work has no influence on the magnetic susceptibility of copper and aluminium, attributing changes reported by earlier workers to the pick-up of ferromagnetic impurities during the cold working process.

The effect of cold rolling on the elastic modulus of copper, brass and aluminium has been studied by Cook, Richards and Bidmead.[242] For both copper and brass, the modulus decreases progressively with the reduction

when measured at 45° to the rolling direction, but the changes are more complex in other directions. The elastic constants of single crystals of copper and several copper alloys have been studied by Neighbours and Smith,[243] and the Bauschinger effect in copper at both normal and elevated temperatures is discussed by Lubahn.[244]

The vapour pressures of several metals including copper have been calculated over a pressure range of 1 to 10^{-10} atmospheres by Snider.[245]

Up to the present, apart from empirical foundry tests for "fluidity", comparatively little attention has been paid to the viscosity of molten metals and alloys. A study of this property in relation to copper and copper alloys is, therefore, particularly opportune.[246] All the viscosity-temperature curves studied, namely, those for copper and a range of copper-silicon, copper-aluminium and copper-tin alloys, showed the same general characteristics. At the melting point the viscosity was comparatively high, but fell very rapidly indeed as the temperature was raised by some 10° or 15° C. At higher temperatures there was a much more gradual decrease in viscosity, which was almost linear with respect to temperature.

Some work on the viscosity of solid copper at temperatures of about 1000° C. has been reported by Pranatis and Pound,[247] who show that definite relationships exist between viscosity and grain size and between viscosity and temperature. The results were in good agreement with the grain boundary diffusion theory of Herring, and the surface tension of copper was calculated.

Damping Capacity

The changes in damping capacities of *alpha* brass, during and after deformation, and the effects of temperature and grain size on this property are discussed in a paper by Köster and Stolte,[248] whilst the changes in damping capacity and shear modulus of worked and recrystallised copper wire have been investigated in relation to the amount of work and grain size by Köster, Bangert and Lang.[249] Using a torsional method, Marsh[250] has determined the damping capacity of wires of copper and certain tin bronzes. While the experimental data may be of value for practical purposes, no very convincing conclusions emerged from the work.

Creep, Fatigue and Shear Properties.

By experiments in an atmosphere of helium, Sweetland and Parker[251] have demonstrated that surface condition has a marked effect on the creep behaviour of copper and aluminium. The formation of superficial oxide films caused a decrease in the rate of creep amounting to as much as 58%. For a study of the mechanism of creep in a typical precipitation-hardening alloy, Olds[252] chose copper containing 3% of silver. At temperatures ranging from 100° to 300° C., he found two distinctly different mechanisms of transient creep, depending upon the temperature of the experiment.

The structural changes during the fatigue of high conductivity copper have been examined by Davies[253] at frequencies between 100 and 150 cycles per minute, using X-ray diffraction methods. At a joint meeting of two sections of the Institute of Metals,[254] a new technique was described whereby microcracks could be observed in copper after only 70–80% of its fatigue life, while oxide precipitation during fatigue tests at room temperature was reported in connection with copper to which 0·01% silicon had been added. In the discussion, reference was made to the determination of fatigue curves for brass and copper at sub-zero temperatures, and to the effect of grain size on fatigue life.

Tests performed several years ago by Welber and Webeler[255] seemed to suggest that the internal energy of copper was not increased by fatigue, rather the reverse. More recently Clarebrough, Hargreaves, Head and West[256] have described experiments which show that the amount of energy stored in copper specimens fatigued for upwards of 10^8 cycles, and the attendant increase of hardness, were of the order which might be expected from material deformed by 30% in tension. This finding is much more credible than that of Welber and Webeler.

The effect of hydrostatic pressure on the shear properties of annealed and cold worked copper, among other materials, has been determined by Crossland,[257] using torsion tests in a pressurised vessel. The strain required to produce failure was significantly increased as the pressure was raised.

Mechanical Deformation

Inhomogeneous deformation in rolling and drawing copper, brass and other metals has been studied by Hundy and Singer,[258] who have shown by means of micro-hardness measurements that surface hardening occurs in copper and brass when it is lightly rolled or drawn. The inhomogeneity is dependent on the working conditions and disappears after moderate working reductions. An investigation into the mechanics of wire drawing has been made by Wistreich,[259] who used copper among other materials for his experiments.

Voce[260] compares the exponential function of strain hardening with the well-known power function of Ludwik, and demonstrates the practical advantages of the former.

Analysis and Testing

Metallography

Based on a patent of the Battelle Development Corporation,[261] Varsavski, Bonchi and Sabato[262] have developed a rapid method of chemical polishing for metallographic examination. Two solutions are recommended, namely :—

	No. 1	No. 2
Nitric acid (sp. gr. 1·4)	30%	17%
Phosphoric acid (85%)	15%	17%
Acetic acid (glacial)	55%	66%
Temperature of operation	85° C.	50° C.

The first of these is said to give good results on copper, but is less successful for brasses. The second is more satisfactory for brasses than for copper. Neither is recommended for tin bronzes. The same authors, with others, have described methods of distinguishing between cuprous oxide and cuprous sulphide in metallographic sections of copper.[263] Strong hydrochloric acid dissolves the oxide but not the sulphide, while a 5% solution of potassium cyanide attacks both.

A report on the determination of grain size has been published reviewing methods currently used for brass.[264]

Chemical Analysis

Kahn and Moyer[265] describe a rapid photometric method for the determination of chromium in bronzes and alloy steels. It is claimed that the procedure is simple

in operation, and gives a satisfactory degree of accuracy and reproducibility. Goldberg[266] has developed an improved method for the analysis of high tensile brasses.

Eddy Current Testing

In recent years the "Probolog", an eddy current device for the internal inspection of tubes, has attracted considerable attention. Warren[267] has described the instrument and outlined its possibilities in the detection of corrosion in the interior of tubes.

The practical applications of the eddy current method for the determination of electrical conductivity appear in a paper by Bunge.[268] He has measured the variations in electrical conductivity by this means in order to study the effect of ageing on the hardness of copper-chromium alloys, the influence of phosphorus on the conductivity of copper, and the conductivity of molten copper in various stages of deoxidation. Another mention of this test in a paper by Gilmour[269] gives examples of its applications, including the detection of surface cracks and other imperfections in the material by conductivity measurements. The test may also be used for identification and sorting of various metals and alloys.

A Thickness Gauge for Electrodeposits

A simple thickness gauge for electrodeposits, designed by the British Non-Ferrous Metals Research Association[270] may be regarded as an important advance in the non-destructive testing of metallic coatings. Like the ordinary thermocouple, the gauge depends on the thermoelectric effect, the interface between the coating and the underlying metal serving as the dissimilar-metal junction. The gauge receives favourable comment from Fletcher[271] in a comprehensive review of process and quality control instruments used in electroplating.

Hardness Testing

The errors introduced in diamond pyramid hardness testing by tilting the specimen have been investigated by Mulhearn and Samuels.[272] The errors are found to be less than 1% if the angle of tilt does not exceed 2°, but for angles greater than 4° the inaccuracy may be quite substantial. Because of this, the measurement of the hardness of gear teeth is difficult, and a portable hardness tester has been designed specifically for this purpose. A recent article[273] gives details of this, together with those of a new general purpose portable hardness testing instrument.

Lysaght[274] has discussed the Rockwell hardness testing of sheet metals and Hardy[275] has contributed some pertinent observations on the anvil effect.

General

The lectures which were delivered at the refresher course of the Institution of Metallurgists in 1954 on the inspection and testing of metals have recently been published,[276] while Shilling[277] has described the methods employed by the A.I.D.

Miscellaneous

The expanding application of the technique of printed circuitry has resulted in many variants of the original process, and circuits are now produced in copper and copper alloys by printing, etching, plating, stamping, spraying and other methods.[278, 279] Copper and copper alloys have been extensively employed in the construction of two powerful accelerators to be used for medical research.[280, 281] The manufacture of copper and copper alloy decorative objects for the home and for furniture fittings, are reviewed by Roesch and Eichin,[282, 283] while Tannheimer[284] has described copper-base church furnishings, dealing with both architectural and decorative features, and the objects and vessels required for religious services.

A particularly lucid and informative history of the development of the copper, zinc and brass industries in this country has been written by Alexander.[285] The account is well authenticated and contains a number of interesting illustrations, especially of the earlier South Wales copper works.

A new book of historical interest is "Elizabethan Copper" by Donald.[286] This is an account of the Company of Mines Royal, which was formed in 1568 mainly to produce copper from mines already being worked near Newlands in Cumberland. The Company subsequently took up properties in Cornwall and established the first copper smelter at Neath in South Wales, where an output of 24 cwt. of blister copper from one day's smelting was regarded as an achievment. The book, which is full of interesting sidelights on the times, deals at length with the smelting, marketing activities and financial operations of the Company.

Excellent illustrations form the basis of an account of bronze casting as practised in Benin, Nigeria.[287] The natives of this district have developed a cult of casting effigies of their leaders and deities in bronze, mainly by the lost wax technique. In older times these were used in savage and often bloody, rituals

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Canadian Order for English Electric

THE ENGLISH ELECTRIC CO., LTD., has received a repeat order for a 132,000 kVA. water-turbine driven alternator from the Aluminium Company of Canada for its underground power station at Kemano in British Columbia. The placing of the order which is valued at $856,000, follows the successful operation of a similar alternator built at the English Electric Stafford works and delivered to Kemano two years ago.

The Development of Ventilating Machines

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The increase in attention paid in recent years to ventilation in workshops, particularly foundries, has led to considerable improvements in working conditions. The necessity for forced ventilation was recognised at least two thousand years ago, and in this article reference is made to some of the methods which have been used since that time.

DURING the last half-century the importance of adequate and efficient ventilation in factories and mines has been increasingly realised. Legislation has emphasised the need to protect workmen from inhaling dusts and fumes which may represent a health hazard, and management has come to recognise that the provision of plant for air purification is an essential, and often a very heavy, capital expenditure.

It is not generally realised that great changes have occurred in ventilating equipment during the last few years; the designing of fans and ducts has become the job of the specialist. It has become apparent that the casual placing of exhaust fans in the walls of buildings is, in most cases, a wasteful and ineffective method of dealing with air contamination; fumes and dust must be removed by ventilating plant designed by the expert to suit each individual process.

Although effective ventilating plant has been developed only during the last quarter of a century, the necessity for forced ventilation was recognised at least two thousand years ago. Pliny (A.D. 55) warned his readers that poisonous gases were liable to accumulate in shallow mines and wells, and he recommended keeping the air in motion by shaking a cloth. Pliny was quoted by Agricola, who illustrated the process in his "De Re Metallica," published in A.D. 1555 (Fig. 1).* Needless to say, this was a most inefficient method of ventilation; Pliny was perhaps unaware that for hundreds of years a much better method had been used in metal mining.

The mining of metals, particularly copper, is an industry of great antiquity; copper was mined before 2000 B.C. Even two or three thousand years ago mines were worked to a depth of a hundred or more feet, and the accumulation of toxic gases in the workings was a hazard which was fully recognised. The mine usually followed a vein of ore which outcropped on the side of a hill. The ore was worked from the outcrop and was followed deeper and deeper into the hillside. At some point it became necessary to dig a vertical shaft into the workings, and ventilation was induced by lighting fires on a platform some distance up the shaft. This produced a current of warm air, which, rising upwards, caused fresh air to be drawn into the workings through the main entrance.

Sixteenth Century Practice

Little is known of the development of ventilation methods between that time and the sixteenth century but Agricola, in his treatise on mining, dealt with the problem of ventilation at some length, and the methods of ventilating mines which he described probably

A—Tunnel B—Linen cloth

Fig. 1.—Agricola's illustration of the methods described by Pliny (A.D. 55) for the ventilation of shallow mines. (Agricola: De Re Metallica—A.D. 1555).

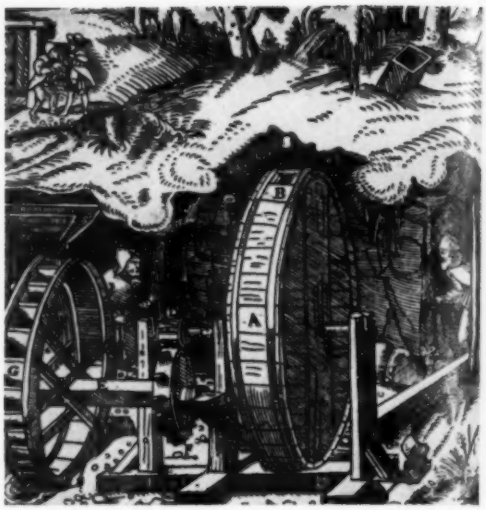
represented the standard practice of the day. He said "if a shaft is very deep and no tunnel reaches to it, or no drift from another shaft connects with it, or when a tunnel is of great length and no shaft reaches to it, then the air does not replenish itself. In such a case it weighs heavily on the miners, causing them to breathe with difficulty, and sometimes they are even suffocated, and burning lamps are extinguished. There is, therefore, a necessity for machines which enable the miners to breathe easily and carry on their work." Forced ventilation was necessary in mines because "stagnant air, both that which remains in a shaft and that which remains in a tunnel, produces a difficulty in breathing" and because of dust, "for the dust which is stirred and beaten up by digging penetrates into the windpipe and lungs, and produces difficulty in breathing and the disease which Greeks call *asthma*."

Agricola emphasised that the only alternative to using ventilating machines in mining was to construct a system of double tunnels, so that natural ventilation would be induced. "If machines of this kind had not been invented, it would be necessary for miners to drive two tunnels into a mountain, and continually, at every two hundred feet at most, to sink a shaft from the upper tunnel to the lower one, that the air passing into the one and descending by the shafts into the other,

* The illustrations from "De Re Metallica" are taken from the translation by H.C. and L.H. Hoover published by *The Mining Magazine* in 1912

A—Wooden barrels
B—Hoops
C—Blow-holes
D—Pipe
E—Table
F—Axle
G—Opening in the bottom of the barrel
H—Wing

Fig. 2.—A method used in the sixteenth century for ventilating mines. The draught was provided by the prevailing wind. (Agricola).



A—Hollow drum
B—Its blow-hole
C—Axle with fans
D—Drum made of rundles
E—Lower axle
F—Its toothed wheel
G—Water wheel

Fig. 3.—A sixteenth century water-driven fan used for ventilating mines. (Agricola).

would be kept fresh for the miners; this could not be done without great expense."

Agricola listed a number of methods for ventilating mines, but did not mention the use of fires. Fires were used, however, for removing arsenical deposits where "the rocks exhale some subtle poison from the minerals, which is driven out by the fire, and this poison is itself raised with the smoke not unlike pompholyx (zinc oxide), which clings to the upper part of the walls in the works in which ores are smelted." Piles of wood were burnt in the workings on Friday, and the workings were not again entered until Monday.

A—Tunnel
B—Pipe
C—Nozzle of double bellows

Fig. 4.—Bellows with the nozzle connected to a conduit to blow fresh air to a mine working. (Agricola).

Ventilation by Wind

The methods of ventilation were classified into three "genera." The first relied on the prevailing wind; the second used fans, and the third used bellows. "The first genus receives and diverts into the shaft the blowing of the wind." One arrangement divided the mine shaft into four quadrants with planking which reached to the bottom of the shaft and projected some distance above the opening. The wind, striking the projection, was diverted into the shaft down one or two of the quadrants, and air was forced out through the others. Another design of this genus is illustrated in Fig. 2. It consisted of a barrel which could rotate on a pipe. The pipe led into a duct which continued to the working place, and the barrel had a blowhole and, diagonally opposite, a fin. "The wind, from whatever quarter of the world it blows, drives the wing straight towards the opposite direction, in which way the barrel turns the blow-hole towards the wind itself; the blow-hole receives the wind, and it is guided down into the shaft by means of the conduit or pipes."

Ventilation by Fan

The second type of blowing machine utilised a fan. This was constructed in the form of wooden paddles which were made to revolve inside a circular wooden casing. To minimise air leakage between the ends of the paddles and the case, the paddles were tipped, either with thin blades of a flexible wood such as poplar, or with two or three rows of goose-feathers which rubbed on the casing when the fan rotated. The case had two blow-holes, one of which was connected to a duct which led to the workings. Air was taken into one hole and was forced through the duct. These fans were driven by men who turned a crank, by water-mills, or by windmills. Water-mills were considered to be the most economical proposition where water was in abundance, "because to turn the crank does not need men who require pay, and because it forces air without cessation

A—Smaller part of shaft
B—Square conduit
C—Bellows
D—Larger part of shaft

Fig. 5.—Bellows with the blow-hole connected to a conduit to remove " pestilential vapours " from a mine working. (Agricola).

through the conduit into the shaft." One of these ventilating machines is illustrated in Fig. 3.

Ventilation by Bellows

Bellows appear to have provided the most efficient method of ventilation. Using bellows it was possible to draw out foul air or pipe in fresh air through long wooden conduits over long distances. The conduit was connected either to the nozzle of the bellows (Fig. 4), or to the blow-hole (Fig. 5). " If the nozzle of the bellows is enclosed in the conduit it draws pure air into itself, but if the blow-hole is fitted all round the mouth of the conduit it exhausts the heavy and pestilential vapours out of the conduit, and thus from the shaft, even if it is one hundred and twenty feet deep." The rate of air replacement which was obtainable with these bellows could not have been very high, but Agricola gives the impression that this was the most satisfactory method of ventilation.

Nineteenth Century Developments

The exhaust fan, as Agricola knew it, must have been a most inefficient machine, and it is not surprising that little more was heard of it for several centuries. With the development of power-driven machinery the dust problem became serious in some industries, and proposals for the improvement of ventilation were often made. Most of the suggested methods of dust removal involved not fans but fast rotating wheels. Thackrah, in 1831, drew attention to the appalling sickness in the flax mills, particularly among the child workers, which he believed was due to dust. He suggested that wheels of this type should be installed in conjunction with ducts cut in the floor: " let a light broad wheel, attached to the machinery, be made to revolve rapidly. A current of air will thus be produced, and this entering the channel will draw down the greater part of the dust, and carry it out of the building." The same principle was involved in the method used for ventilating workshops where knives were ground and needles pointed. In these industries there was shocking mortality from silicosis,

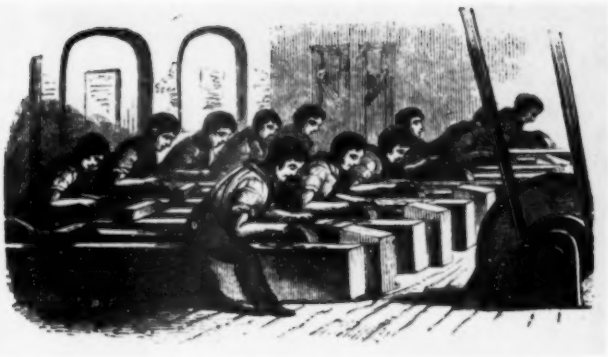
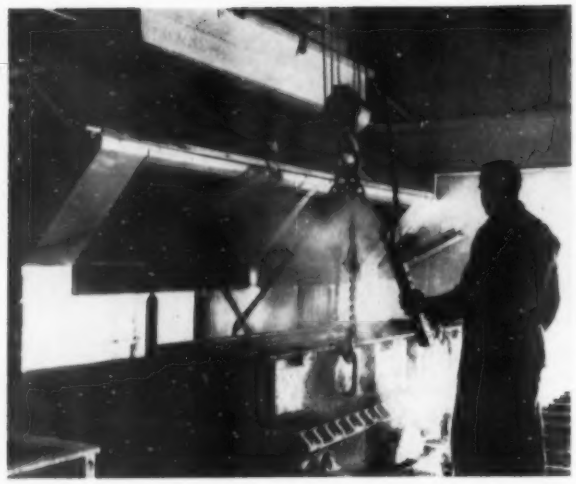


Fig. 6.—Exhaust ventilation applied to grinding wheels during the last century. The grindstone was built into a wooden duct to which an exhaust fan was connected. (Tomlinson: Illustrations of Useful Arts, Manufactures and Trades—A.D. 1856).

due to the use of sandstone grinding wheels. Tomlinson, in 1867, described how the wheels were boxed in so that the air stream which was induced by the grindstone carried the dust into a duct, from whence it was taken out of the building. " The only effectual remedy for this is to box in the stone and connect it with a channel passing into the open air, and so to rarify the air in this channel by means of a revolving fan, that the air of the workshop shall always tend to move in a current, and blow downwards upon the stone, so as to convey the metallic and stony dust into the shaft. The stones for the dry grinding of cutlery are arranged on this plan with wonderful benefit to the health of the workman." This was illustrated (Fig. 6) in his book " Illustrations of Useful Arts, Manufactures and Trades " (1867). It is interesting that the dust control of the modern swing frame grinder (Fig. 7) is designed in a similar way; the

Courtesy of the British Steel Castings Research Association

Fig. 7.—Modern exhaust ventilation applied to a swing frame grinder. The grinder is enclosed except for a small opening through which the dust of respirable size is drawn. Heavier particles of non-respirable size are not affected by the exhaust draught. The principle of this exhaust system resembles that described by Tomlinson in 1856.



Courtesy of The Sturtevant Engineering Co., Ltd.

Fig. 8.—Modern ventilation equipment for combating the silicosis risk in steel foundries. The ventilation hood is placed at the side of the mechanical shaker which removes the sand from the castings, in such a position that the workers cannot pass between the casting and the hood.

wheel is encased and the casing is connected to an exhaust duct, although high powered exhaust is now used to carry away the dust.

No important improvements in the exhaust fan were made until the nineteenth century; even at this time methods of dust control were not taken seriously. A Royal Commission was appointed in 1862 to inquire into the health of workers in English metalliferous mines. Their report showed that they did not consider dust to be responsible for the pneumoconiosis then prevalent in mines, but they did consider the dust to be a nuisance. One passage in their report is significant, in that it emphasises that little was being done to improve ventilation, although more efficient exhaust fans had become available. It contains the sentences "It does seem surprising how little has been the progress of ideas in the adaptation of ventilating machinery. There have, however, been remarkable improvements in the mode of construction of the fan, and a better theory of its mode of action has been propounded."

Modern ventilation methods have been developed only during the last fifty years. The highly efficient extractors which are an essential part of the equipment of every large works where dust is produced, became possible only when adequate electric motors were available. But even when efficient extractor fans had been designed, the principle of extracting the dust at its source was not generally applied. The only efficient method of removing dust is to extract it through hoods which are as near as is practicable to the origin of the dust (an example of a modern extractor-hood is shown in Fig. 8) or, better still, to extract it from a cover which totally encloses the machine. The realisation of this fact, which should have been obvious from the outset, has done as much to prevent the contamination of industrial atmospheres as has the striking improvement in ventilating machinery.

E.S.C.'s Tinsley Park Developments

English Steel Corporation, Ltd., announce that approval has now been received from the Iron and Steel Board for the first stage of the development of the area at Tinsley Park, Sheffield. This site was acquired by the Company in 1954 so that an adequate area would be available for the development of the heavy industries which are traditional to Sheffield.

A geological survey of the area is in progress, and site levelling is scheduled to commence towards the end of 1956. The first stage will involve the levelling of a large part of the site and the erection thereon of open hearth melting furnaces and heavy forging plant. Facilities will also be made available for the production of steel castings heavier than those now manufactured at the Grimesthorpe Works of the Corporation. The cost of the scheme is estimated at £15,000,000, but expenditure in the next two years will not be great, as the specialised nature of the plant involves considerable design work and a long period of manufacture. During this time, preparation of the site will progress.

When this stage of the development is completed, the Corporation hopes to be in a position to meet demands from home and abroad for the heaviest types of forgings and castings required by the engineering industry, and thus to retain in Sheffield a branch of the heavy industry which was established there by Vickers, Ltd., and Cammell Laird & Co., Ltd., a hundred years ago. The production facilities to be provided will meet an urgent national need, as plant of similar capacity is already available to competitors in the United States and in Europe, and unless an early development takes place, this country will be unable to meet the ever-growing demand by the engineering industry for large indivisible steel components.

An Industrial Development Certificate has already been granted by the Board of Trade for the erection in one corner of the site of a new works to house part of the Spring Plant at Grimesthorpe Works. The present premises are old and cannot be adapted to the requirements of modern production. In the new premises a completely new layout for the manufacture of laminated and coil springs will be installed to meet the demands of the automobile industry.

Ipsen European Office

Ipsen Industries, Inc., Rockford, Illinois, recently announced the opening of the main office of Ipsen International at Weteringschaus, 151 Amsterdam C., Holland. This headquarters will be headed by Dr. R. J. Rohr who recently joined the Ipsen organisation. He will direct European operations and co-ordinate all sales activities in merchandising the complete line of Ipsen controlled atmosphere furnaces, generators and control equipment.

Hungary to Build Aluminium Ship

Hungary's first all-aluminium sea-going ship is being planned by the Metal Research Institute, and is scheduled to be on the stocks of the Gheorghiu-Dej Danube shipyards before the end of this year. It will have the capacity of a vessel of 1,300 tons but will weigh a third of the normal weight.

British Standards for Aluminium and its Alloys—The 1955 Revisions

By E. Elliott, A.Met., A.I.M.

Aluminium Development Association

A summary is given of the major changes involved in the recently published revisions of B.S. 1470–1477 and B.S. 1490, and some account of the reasons for them, together with a general note on the importance of keeping standards abreast of progress.

(*continued from page 112 of the March issue*)

B.S. 1470–1477 : 1955—Wrought Aluminium and Aluminium Alloys for General Engineering Purposes

Nomenclature

As with castings, a most important part of the wrought standards is the system of nomenclature, now widely accepted and understood. The system is of necessity somewhat more complex than that of B.S.1490, and while it has not changed in principle by the 1955 revisions, there have been essential additions and deletions.

The different grades of pure aluminium and the aluminium alloys are listed under numbers, and the same number has been used to indicate any given grade of pure aluminium or aluminium alloy in whatever wrought form it may be obtainable. They range from 1 to 18, with some omissions, and with the addition of numbers 20 to 30 immediately following 10; this is explained later. The prefix letters have the following meanings :—

- N Non-heat-treatable alloys, those which are not strengthened by heat-treatment.
- H Heat-treatable alloys, those which are strengthened by heat-treatment, although in some cases they may on occasion be supplied or used without such treatment.

Between the prefix letter N or H, and the alloy number, is placed a further letter which indicates the wrought form. The meanings of these are as follows :—

- S Sheet (up to and including 0·252 in. thick) and strip (up to and including 0·192 in. thick) (B.S.1470).
- C Clad sheet and strip (B.S.1470)
- T Drawn tube (B.S.1471).
- F Forgings and forging stock (B.S.1472).
- R Rivet stock (B.S.1473).
- B Bolt and screw stock (B.S.1473).
- V Extruded round tube and hollow sections (B.S.1474).
- G Wire (B.S.1475).
- E Bars, rods and sections (B.S.1476).
- P Plate (B.S.1477).
- PC Clad plate (B.S.1477).

Thus the letters NG indicate non-heat-treatable alloys in the form of wire, HS heat-treatable alloys in the form of sheet and strip, and HPC heat-treatable alloys in the form of clad plate. It will be noted that, as far as possible, the method of manufacture has not been restricted, thus the letter E refers to bars, rods and sections, not specifically to extrusions. If satisfactory bars can be made by rolling they may be accepted as complying with the standard.

By the above method, two letters and a number designate the composition, type and wrought form of any standard material; it is also necessary to indicate the condition of heat-treatment or temper, by symbols following the alloy number. These symbols are as follows for aluminium and the non-treatable alloys :—

- O Material in the annealed condition.
- OD Material which has been annealed and lightly drawn (at present applicable only to rivet stock).
- ¼H, ½H, ¾H, H The various harder tempers in the case of sheet and strip, plate, drawn tube, wire and rivet stock.
- M Material in the "as-manufactured" conditions, e.g. as-rolled, as-extruded, straightened and/or drawn to size, or as forged in the case of forgings.

For the heat-treatable alloys, the suffix letters have the following significance :-

- O Material in the annealed condition.
- M Material in the "as-manufactured" conditions, e.g. as-rolled, as-extruded, straightened and/or drawn to size, or as-forged, without subsequent heat-treatment of any kind.
- OD Material which has been annealed and lightly drawn (at present applicable only to rivet, bolt and screw stock).
- T Material which has been solution-treated and requires no precipitation-treatment.
- W Material which has been solution-treated and will respond effectively to precipitation-treatment.
- WP Material which has been solution-treated and precipitation-treated.
- WD Material which has been drawn after solution-treatment (at present applicable only to wire).
- P Material which has been precipitation-treated only.

Of the above, the designations OD and WD are new, and P has previously been used only in B.S.1490 to apply to casting alloys. The following are examples of the system of nomenclature.

TABLE IV.—SUMMARY OF CHEMICAL COMPOSITIONS OF WROUGHT ALUMINIUM AND ALUMINIUM ALLOYS LISTED IN B.S.1470 : 1477.

(Where no range is given the figures are maxima.)

Material	Al %	Cu %	Mg %	Si %	Fe %	Mn %	Ni %	Zn %**	Pb %**	Sn %**	Ti etc. % (optional)*	Cr %	Sb %
1	99·99	†See below	—	†See below	†See below	—	—	—	—	—	—	—	—
1A	99·8	0·02	—	0·15	0·15	—	—	—	—	—	—	—	—
1B	99·5	0·05	—	0·3	0·4	0·05	—	—	—	—	—	—	—
1C	99	0·10	—	0·5	0·7	0·1	—	0·10	—	—	—		—
N2	Remainder	0·10	**0·25	10·0–13·0	0·6	0·5	**0·2	0·2	0·05	0·05	—	—	—
N21	Remainder	0·10	**0·25	4·5–6·0	0·6	0·5	**0·2	0·2	0·05	0·05	—	—	—
N3	Remainder	0·15	—	0·6	0·7	1·0–1·5	—	0·1	—	—	0·20	—	—
N4	Remainder	0·10	1·8–2·7	0·6	0·7	0·5	—	0·1	—	—	0·20	0·5	—
N5	Remainder	0·10	3·0–4·0	0·6	0·7	1·0	—	0·1	—	—	0·20	0·5	—
N6	Remainder	0·10	4·5–5·5	0·6	0·7	1·0	—	0·1	—	—	0·20	0·5	—
N5/6	Remainder	0·10	5·5–5·5	0·6	0·7	1·0	—	0·1	—	—	0·20	0·5	—
N7	Remainder	0·10	6·5–7·5	0·6	0·7	0·5	—	0·1	—	—	0·20	0·5	—
H9	Remainder	0·10	0·4–0·9	0·3–0·7	0·6	0·5	—	0·1	—	—	0·20	—	—
H10	Remainder	0·10	0·4–1·5	0·60–1·3	0·6	0·6	—	0·1	—	—	0·20	0·5	—
H20	Remainder	0·15–0·40	0·8–1·2	0·4 –0·8	0·7	§0·2–0·8	—	0·2	—	—	0·20	§0·15–0·35	—
H30	Remainder	0·10	0·4–1·5	0·60–1·3	0·6	0·40–1·0	—	0·1	—	—	0·20	0·5	—
H11	Remainder	1·0–2·0	0·5–1·2	0·8–1·3	0·7	1·0	**0·2	0·2	0·05	0·05	0·3	—	0·05
H12	Remainder	1·8–2·8	0·6–1·2	0·5–1·3	0·6–1·2	0·5	0·6–1·4	0·2	0·05	0·05	0·3	—	0·05
H14	Remainder	3·5–5·0	0·4–1·2	0·7	0·7	0·4–1·2	**0·2	0·2	0·05	0·05	§0·3	§0·3	0·05
H15	Remainder	3·5–4·8	0·85	0·90	1·0	1·2	**0·2	0·2	0·05	0·05	§0·3	§0·3	0·05
H18	Remainder	1·8–2·7	1·2–1·6	1·3	0·6–1·2	**0·2	0·6–1·4	0·2	0·05	0·05	0·3	—	0·05

* Titanium and/or other grain refining elements may be present at the option of the supplier provided the total content does not exceed 0·20%, 0·3%, according to the specification.

† The combined copper, silicon and iron content shall not exceed 0·01%.

‡ Either manganese within the limits stated or chromium within the limits stated shall be included.

§ Titanium and/or other grain refining elements and/or chromium may be present at the option of the supplier provided the total content does not exceed 0·3%.

** The supplier shall undertake that the material does not contain impurities in excess of the amount shown.

GIA–M indicates pure aluminium of grade 1A, in the form of wire, in the as-manufactured condition.

NS3–¾H indicates non-heat-treatable alloy No. 3 in the form of sheet or strip, in the three-quarter hard temper.

HE30–WP indicates heat-treatable alloy No. 30 in the form of bar, rod or section, in the fully-heat-treated condition.

HPC15–W indicates heat-treatable alloy No. 15 in the form of clad plate, which has been solution-treated and which will respond effectively to precipitation-treatment.

Materials

Where grades of pure metal or alloys appear in more than one standard in the series B.S.1470–1477, as, of course, the great majority do, the composition requirements for each grade of pure metal and each alloy are the same throughout the series. This is obviously of great importance in standardisation, and it also makes possible a broad general assessment of changes in materials that have been made by the 1955 revisions, before attention is turned to individual standards. The specified compositions of all the materials concerned, together with their symbols, are given in Table IV.

The three grades of pure aluminium, namely 1A, 1B and 1C, containing, respectively, not less than 99·8, 99·5, and 99% of the metal, are obtained by selection from the produce of the Hall-Héroult cell. They have now been augmented by the addition of material 1, containing not less than 99·99% aluminium, which is prepared by the second refining process, the three-layer electrolytic process, and is already well-known as super-purity aluminium. Its widespread uses, meriting its standardisation, have recently been summarised by Spillett.[4]

The aluminium-silicon alloys, N2 and N21, appear only as wire ; they are used as welding or brazing filler materials, and are not appreciably changed.

Alloy N3, aluminium–1¼% manganese, is one of the main products of the aluminium industry, and has been retained without major change. The aluminium-magnesium binary non-heat-treatable alloys N4, N5, N6, N7 and N5/6 have also not required much alteration, although their maximum copper content has been reduced from 0·15 to 0·10%. This is actually only a recognition of commercial practice, since, in view of the importance of keeping the content of this element low to retain the maximum resistance to corrosion, a minimum content is always aimed at. Alloy N5/6, used only as plate, is considered separately under B.S.1477.

The strongest wrought aluminium alloys used for general engineering purposes in this country are the aluminium-copper-magnesium types, represented in B.S.1470–1477 by H11, H14 and H15, the rivet alloy H13 having been dropped, as it is now little used. Much research has been done since the war to determine the optimum composition for alloy H15, principally in its aircraft versions ; the " X " composition will be remembered by many as the designation used during the period of service trial of the variety which has now been included for H15 in B.S.1471–1477. This has involved an increase in maximum permissible magnesium content from 0·6 to 0·85%, and the top limit on silicon has been reduced from 1·5 to 0·90%. This had already been introduced to B.S.1470 by amendment slip, but it is now made general in the whole series.

Forging alloys exclusive to B.S.1472 are considered below under that standard.

That major group of alloys, the heat-treatable aluminium-magnesium-silicon type, embracing the principal structural alloys of aluminium, have been left to the last ; they require more extensive consideration, since it is within this group that the most important changes have been made. In B.S.1470–1477 : 1948–1951 two such alloys were included, namely H9 and H10. The former is continued without great change in the revised standards, although its upper limit on copper is reduced from 0·15 to 0·10%. The limits on magnesium and on silicon in H9 are such that the analyses of material produced usually indicate what might be termed a " balanced " alloy, that is, the two elements are in proportions such as to provide the intermetallic compound Mg_2Si without great excess of either element. The proportion is about 49 magnesium to 28 silicon ; readers of foreign specification will have seen aluminium-magnesium-silicon compositions where no figure is quoted for silicon, but it is required to be a stated percentage of the magnesium figure.

Alloy H9 has a wide field of service, but its strength, while adequate for many uses, is rather low for such applications as building structures, coach frames, lorry bodies and the like, if the maximum advantage in strength/weight ratio and cost is to be achieved. The proof stress and tensile strength of wrought aluminium-magnesium-silicon alloys may be improved over those of H9 in a number of ways. A somewhat greater content of Mg_2Si may be provided ; an excess of either magnesium or silicon may be included, the silicon being much the more efficient ; and/or other elements may be added. Hitherto, B.S.1470–1477 have covered, in addition to H9, only H10 in this class of alloy. H10 contained a little more Mg_2Si, and an excess of silicon ; further, any content of manganese from zero to 1·0% was permitted. The limits on magnesium and on silicon were wide, and this fact, in conjunction with the permissive manganese content, has meant that quite a variety of compositions have been supplied within this specification, and complying with the requirements as to strength and ductility.

Research work and service experience have combined to show that, while H10-type alloys are all similar in mechanical properties and resistance to corrosion in the solution-treated condition, a manganese content of, say, 0·5% or more confers an appreciable advantage in proof stress and tensile strength on a fully-heat-treated alloy ; there is also evidence that such a composition has resistance to high stress in highly aggressive atmospheres even better than H10 without manganese, which is, of course, itself notably corrosion-resistant. Reference should be made here to the work of Harris and Varley[5] and of Haughton and Phillips[6]. In B.S.1470–1477 : 1955, therefore, a new alloy has been added, namely, H30, which is similar to the old H10 but with a mandatory manganese content of 0·4–1·0%, and with 1 ton/sq. in. higher minimum proof stress and tensile strength in the fully-heat-treated condition. H10 itself remains in the standard, with manganese limits of nil–0·6%, thus permitting the manufacture of a composition with manganese sufficient to ensure resistance in the fully heat-treated condition to severe corrosive conditions with high stress, without the special strength requirements of H30.

The only other important compositional changes in H10 and H30 are that the lower limit on silicon is 0·60% as against 0·75% in the previous H10, and the maximum content of copper has been reduced from 0·15% to 0·10%.

In the U.S.A. and Canada, the principal aluminium-magnesium-silicon alloy is of balanced Mg_2Si type, the extra strengthening, obtained in this country by excess silicon, being dependent with the American alloy upon an addition of about 0·25% of copper. Although agreeing that the addition of copper to an alloy of the H10 type reduces its corrosion resistance appreciably, the protagonists of the copper-bearing material claim that with a balanced alloy the effect is less serious, and furthermore, an addition of about 0·25% of chromium has a beneficial effect, the resulting alloy having corrosion resistance at least as good as that of H10. Experience and investigation over the post-war years has led to an increasing acceptance of this view in this country, and several companies have offered the aluminium-magnesium-silicon-copper-chromium alloy and a variant in which the chromium is replaced by about 0·7% of manganese. Both these alloys have now been added to

TABLE V.—GENERAL GUIDE TO THE SELECTION OF ALUMINIUM AND ITS ALLOYS IN THE WROUGHT FORMS.

B.S.1470–77 (1955)	Tensile Strength Range* (tons/sq. in.)	Suitability for: Cold Forming†	Machining	Fusion Welding‡: Oxy-Gas	Fusion Welding‡: Inert Gas Shielded Arc	Resistance Spot Welding	Resistance to Atmospheric Attack
NON-HEAT-TREATED							
1	3·5–6·5	V	P	V	V	P	V
1A	4–8	V	P	V	V	P	V
1B	4·5–8·5	V	P	V	V	G	V
1C	5–9	V	F	V	V	G	V
N3	6–11·5	V	F	V	V	V	V
N4	11–15	G	G	G	G	V	V
N5	14–17	G	G	F	G	V	V
N6	17–19	G	G	F	G	V	V
N5/6	17–18	G	G	F	G	V	V
N7	20–23	F	G	P	G	V	G
SOLUTION-TREATED							
H9	9	G	G	G	G	G	V
H10, 20, 30	12–14	G	G	F	G	G	G
H11	17	G	G	U	G	V	F
H14	25	F	G	U	G	V	F
HC14	24	F	G	U	F	V	G
H15	20–26	F	G	U	G	V	F
HC15	25	F	G	U	F	V	G
FULLY HEAT-TREATED							
H9	12	G	V	G	G	G	G
H10, 20, 30	18–20	F	V	F	G	G	G
H11	23–25	P	V	U	G	U	P
H12	27	P	V	U	G	U	P
H15	28–32	P	V	U	G	V	P
HC15	27	P	G	U	F	V	G
H18	25	U	V	U	G	U	F

V = Very good. G = Good. F. = Fair. P = Poor. U = Unsuitable.

* Where strength varies with temper or form of material a minimum strength range is shown.

† Ratings for non-heat-treatable materials vary with temper, and those indicated are for material in the annealed or other optimum condition for cold forming.

‡ Ratings are given for correct technique and filler rod and take into account the properties of material after welding. Inert gas welding of alloys H14 and H15 is still in the experimental stages.

B.S.1470–1477 : 1955, under the designation H20, with the same mechanical properties as H10.

The above is a much simplified explanation of the origins of alloys H10, H20 and H30, but other properties than those standardised are also important. In structures, modulus of elasticity affects design ; that of H20 and H30 is somewhat higher than that of H10. Alloy H20 is claimed to have slightly better shock resistance and formability than the other two, while H10 is stated to be more readily extruded into complicated shapes, and to provide a good surface and be more suitable for anodising. All the alloys are weldable, especially by the modern shielded-arc processes.

The differences in properties between H10, H20 and H30 are of small degree, but in certain applications may be of great importance. In selecting between them, therefore, opinion should be sought from those closely acquainted with their relative merits. Indeed, selection of material is a most important factor in the correct application of aluminium and its alloys, and Table V forms a guide only to this function ; it should always be supplemented where necessary by advice from the manufacturers or the A.D.A.

Dimensional Tolerances

There have been important alterations in tolerances in the various standards, and it is interesting to examine them together. In B.S.1470, the limits on lateral curvature of strip have been tightened, and a similar requirement added for sheet. Thickness tolerances have been extended to lower gauges, and shearing tolerances simplified and also made applicable to strip up to 2 ft.

wide. In the other standard for flat rolled products, B.S.1477, tolerances on the width and length of plate have been added. It is noteworthy that this is the only standard in which a table of tolerances is given in both English and metric values; this duplication of the thickness tolerances in B.S.1477 shows the importance of the international aspect of aluminium alloy plate in shipbuilding.

The increasing use of extruded tube has made essential some measure of standardisation of this product, and it was felt that for commercial reasons it could not be dealt with by simply adding extra tables of tolerances to B.S.1471. That standard has therefore been confined to drawn tubes, and B.S.1474 now covers extruded tubes. In B.S.1471, there have been changes in the presentation of tolerances, and extra sizes have been included. In B.S.1474, there are three classes of tolerance on wall thickness of tubes, of increasing stringency from A through B to C, while a single table of diametrical tolerances is applicable to all outside diameters, but to the inside diameters of class A and class B tube only. An appendix on section properties of tubes, for the information and guidance of designers, appears in both standards.

B.S.1474 also embraces hollow sections, and two classes of tolerances are tabulated for wall thickness, with one class for overall dimensions, and a maximum allowance of 0·005 in./in. applicable to concavity and convexity. In B.S.1476, confined to solid bars, rods and sections, the principal changes in dimensional tolerances are for hexagon bars, for which a new table has been inserted, covering the new unified bolt sizes, in addition to B.A., B.S.F. and B.S.W. sizes, for both general engineering and aircraft requirements. In the table of tolerances on thickness of regular sections, new sizes have been covered, thus reducing the number of sizes to be regarded as special sections.

There are no changes in dimensional tolerances in B.S.1473, but in B.S.1475, covering wire, the formerly universal limits on diameter of ± 0·002 in. now apply only down to 0·048 in.; below that down to 0·028 in., the tolerance is ± 0·001 in., while from 0·028 in. to 0·012 in. the limits are ± 0·0005 in.

No mandatory dimensional tolerances are specified in B.S.1472; an appendix gives, for information only, those adopted by the National Association of Drop Forgers and Stampers.

A brief summary will now be given of the other principal changes in individual standards.

Individual Specifications

*B.S.*1470 : 1955—*Sheet and Strip*

An important addition to this standard is super-purity aluminium, in the soft, half-hard and hard tempers, with the designation S1. This material has extensive applications, particularly in the building trade for roofing and flashing. Alloys HS20 and HS30 have been included, and as well as the heat-treated conditions these alloys and HS10 have been covered in the O condition, principally so that the purchaser who wishes to carry out drastic forming may use annealed material and apply heat-treatment subsequently.

A quarter-hard temper has been added for alloy NS4. With alloys NS5, NS6 and NS7 the proof stress values on annealed material are now given for information only; this is because in the soft condition the important property for these materials is ductility rather than elastic strength. Similarly, maximum tensile strengths only are now specified for various grades of pure aluminium in the O condition. There are no other important changes in specified mechanical properties.

*B.S.*1471 : 1955—*Drawn Tube*

The symbol T denotes drawn tube only, and the necessary change in the title of the standard has been made. With the pure aluminium tubes, ranges of tensile strength have been discontinued in favour of maxima for annealed tubes, and minima for hard-drawn ones. As with sheet, proof stresses for annealed aluminium-magnesium alloys are now included for information only. HT10, HT20 and HT30 are all present in both W and WP conditions, and HT9 has been added to the standard in these conditions, and also as-drawn, M, without subsequent heat-treatment, since HT9–M enjoys considerable application for general purposes.

In drawn tube form, minimum strength properties are higher for heat-treated alloys than in other wrought forms, as a result of the effect of drawing. A footnote to alloys HT14 and HT15 makes clear that if the user re-heat-treats the material, he may not attain the properties specified for the tube as supplied.

*B.S.*1472 : 1955—*Forgings and Forging Stock*

The important changes in materials in this standard are that HF11 and HF30 have been added, while HF17 has been discontinued, in view of its very small volume of use. There are no notable changes in mechanical property requirements, but the arrangement of the standard has been amended. Thus, although there are still four sections, covering specific and general clauses for forgings and for stock for forging, forging stock has been inserted in the sections dealing with forgings, and properties for it are given in these sections. Mechanical properties for extruded forging materials are listed in the section on stock for forging, but this section also covers cast material, for which properties are to be agreed between supplier and purchaser. A useful appendix gives, for information only, properties to be expected on test pieces cut longitudinally from forgings up to 4 in. diameter.

It will be noted that alloy H20 has not been included in this standard; this is in line with production practice, both here and in the U.S.A. and Canada.

*B.S.*1473 : 1955—*Rivet, Bolt and Screw Stock for Forging*

Previously B.S.1473, 1474 and 1475 were bound together in one volume with the general title "Wire"; they have now, of course been separated into individual documents.

The title of B.S.1473 has been changed; it was previously "Wire for Rivets," and now covers stock for rivets, bolts and screws which are made by heading either hot or cold (in practice, principally cold). It is still concerned with material $\frac{3}{8}$ in. diameter and under, but the word "stock" has been used, rather than "wire" with a view to a possible future extension of the scope of the standard to include material for the manufacture of large rivets as standardised in B.S.1974 : 1953 "Large Aluminium Rivets $\frac{1}{2}$ in. to 1 in. Nominal Diameter." In B.S.1473 a new temper designation, OD, indicates annealed material lightly drawn; stock in this condition helps to ensure round heads in rivet manufacture.

The standard is divided into three sections, namely, section one, embodying general clauses; section two, specific clauses for rivet stock; and section three, specific clauses for bolt and screw stock. Rivet stock has the symbol R, as previously, while bolt and screw stock has a new designation B. In the section devoted to rivet stock, there are considerable changes in materials. Thus NR5 has been added, in view of its extensive use for small rivets for boat and shipbuilding, and HR13 is omitted since its general engineerlng applications are now very slight. Another important addition is alloy HR30, both solution-treated and fully heat-treated.

The alloys included as bolt and screw stock are NB6–½H, HB30–W and WP, and HB15–WP, the conditions of supply of the heat-treatable alloys being such as to permit the bolt and screw manufacturer to heat-treat the material after forging, where this is necessary; this follows the practice already established with alloy HR14.

*B.S.*1474 : 1955—*Extruded Round Tube and Hollow Sections*

B.S.1474 dealt formerly with welding wire, which has now been incorporated in B.S.1475. B.S.1474 : 1955 is therefore a completely new standard, with no connection with its predecessor. The symbol V has been adopted for extruded tube and hollow sections, and materials 1A, 1B, 1C, N4, N5, N6, H9, H10, H20, H30, H11, H14 and H15 have been included in this form. The non-heat-treatable materials are of, course, in the M condition only, and have the same specified properties as in B.S.1476, covering solid bars, rods and sections; this is also the case with properties of the heat-treatable alloys, which are covered in both conditions of heat-treatment, where applicable, and in the M condition for the aluminium-magnesium-silicon alloys. The new condition P, applicable to HV9 is discussed under B.S.1476.

*B.S.*1475 : 1955—*Wire*

The necessity for separate standards for welding wire and for wire for general purposes has long been doubted, and both products have now therefore been incorporated in B.S.1475 under the comprehensive title "Wire." Those grades of pure metal and alloys that are used as welding wires are included in the M condition, without specified mechanical properties; in all cases except NG2, NG21 and NG5 they also appear in other conditions. Alloy N7, previously included with the welding wires, is now so infrequently used that it has been omitted from the standard.

A notable material addition is super-purity aluminium wire, which, in addition to its applications in jewellery, is used for welding and for metal spraying in the manufacture of electrical capacitors. The other grades of pure aluminium all have the M, O and H conditions, as is the case with NG3, NG4 and NG6, the last also being covered in the half-hard temper.

Turning to heat-treatable alloys, HG9 is present in four conditions, namely, O, W, WP, and WD. This last is a new temper designation, representing material drawn after solution treatment; the minimum tensile strength for WD is 15·0 tons/sq. in., as against 12·0 tons/sq. in. for WP. Alloys H10 and H20 are not covered by B.S.1475, only HG30 being included from this group, in the M, O, W and WP condition. The list is completed by HG14–T and HG15–W and WP.

TABLE VI.—B.S.1476 : 1955. BARS, RODS AND SECTIONS. SUMMARY OF MECHANICAL PROPERTIES.

Material	Size of Material	0·1% Proof Stress (min.) tons/sq. in.	Tensile Strength (min.) tons/sq. in.	Elongation % on 2 in. or $4\sqrt{A}$ (min.)
ALUMINIUM				
E1A—M		—	3·5	30
E1B—M		—	4·0	25
E1C—M		—	4·0	20
NON-HEAT-TREATABLE ALUMINIUM ALLOYS				
NE4—M		—	11·0	18
NE5—M	Up to and including 2 in.	*6·0*	14·0	18
	Over 2 in.	*6·0*	13·0	18
NE6—M		*8·0*	17·0	18
NE7—M	Up to and including 2 in.	*9·0*	20·0	18
	Over 2 in.	*8·0*	20·0	18
HEAT-TREATABLE ALUMINIUM ALLOYS				
HE9—M or O		—	7·0	15
—W	Up to and including 6 in.	5·0	9·0	18
	Over 6 in.	5·0	8·0	15
—P	Up to and including ½ in.	7·0	10·0	10
—WP	Up to and including 6 in.	10·0	12·0	12
	Over 6 in.	8·0	10·0	8
HE10—M or O		—	7·0	15
—W	Up to and including 6 in.	7·0	12·0	18
	Over 6 in.	6·0	11·0	15
—WP	Up to and including 6 in.	15·0	18·0	10
	Over 6 in.	13·0	16·0	7
HE20—M or O		—	7·0	15
—W	Up to and including 6 in.	7·0	12·0	18
	Over 6 in.	6·0	11·0	15
—WP	Up to and including 6 in.	15·0	18·0	10
	Over 6 in.	13·0	16·0	7
HE30—M or O		—	7·0	15
—W	Up to and including 6 in.	7·0	12·0	18
	Over 6 in.	6·0	11·0	15
—WP	Up to and including 6 in.	16·0	19·0	10
	Over 6 in.	14·0	17·0	7
HE11—W		12·0	20·0	15
—WP	Up to and including ½ in.	18·0	22·0	8
	Over ½ in. up to and including 3 in.	22·0	26·0	8
	Over 3 in. up to and including 6 in.	20·0	25·0	8
	Over 6 in. up to and including 8 in.	17·0	23·0	6
HE14—T	Up to and including ½ in.	14·0	24·0	12
	Over ½ in. up to and including 3 in.	15·0	25·0	12
	Over 3 in. up to and including 6 in.	15·0	25·0	10
	Over 6 in. up to and including 8 in.	14·0	24·0	10
HE15—W	Up to and including ½ in.	14·0	24·0	12
	Over ½ in. up to and including 3 in.	15·0	25·0	12
	Over 3 in. up to and including 6 in.	15·0	25·0	10
	Over 6 in. up to and including 8 in.	14·0	24·0	10
—WP	Up to and including ½ in.	24·0	28·0	8
	Over ½ in. up to and including 1 in.	26·0	30·0	8
	Over 1 in. up to and including 3 in.	27·0	31·0	8
	Over 3 in. up to and including 6 in.	26·0	30·0	8
	Over 6 in. up to and including 8 in.	24·0	28·0	8

NOTES.

1 The elastic modulus of H10 may lie at the lower end of the range $9·5 \times 10^6$–$10·5 \times 10^6$ lb./sq. in., while those of H20 and H30 will lie at the higher end of this range.

2 Figures in italics are for information only.

It was necessary to glance briefly through the materials, since in this respect B.S.1475 : 1955 is considerably altered from B.S.1475 : 1949, even when allowance is made for the inclusion of welding wire. This is due to the recent rapid advances in aluminium wire production and application, and also to the fact that the wire-drawer is able so readily to offer widely varying properties by variations in drawing sequences, and their combination with heat-treatments, where applicable.

*B.S.*1476 : 1955—*Bars, Rods and Sections*

The only new alloys included in B.S.1476 : 1955, covering solid bars, rods and sections, are H20 and

H30, although there are changes in conditions of heat-treatment. Thus, all the aluminium-magnesium-silicon alloys are present in the M or O, W and WP conditions, while HE9 is also covered in the P condition, which was previously only applied to castings. The explanation of this condition is that when HE9 is extruded in thin section (the P condition applies only up to $\frac{1}{2}$ in. thickness), the air-quenching effect is sufficient to retain the intermetallic compound Mg_2Si in solution in large measure; in other words, it acts as a solution-treatment. Precipitation-treatment then gives an enhancement of strength approaching but not quite attaining that of the WP condition. Material in the P condition obviously costs less to produce than the WP, and is satisfactory for a number of applications; glazing bars are an example.

Fully heat-treated alloy HE11 is standardised in four ranges of size, and as a result of practical experience, the properties specified for these sizes have had to be adjusted—upwards in some sizes and downwards in others.

In the non-heat-treatable alloys, the only notable alteration is that the proof stress values are now quoted only for information. Table VI summarises the mechanical property requirements of B.S.1476, as representative of the series.

*B.S.*1477 : 1955—*Plate*

B.S.1477 : 1951 was in the nature of an experiment; knowledge of plate was limited, particularly over about $\frac{3}{4}$ in. thick, and the foreword of the standard particularly asked for comments and suggestions to help with the first revision. During the subsequent four years, a good deal of experience has been gained of the manufacture and use of aluminium alloy plate, so that B.S.1477 : 1955 has behind it appreciably more authority than its predecessor.

The most interesting material in B.S.1477 is undoubtedly NP5/6. This alloy has received a considerable measure of international attention as the first specification for shipbuilding plate in aluminium alloy, and has, in general, met with approval in other countries, both in Europe and over the Atlantic. Similar specifications are now appearing oversea. The specified magnesium content of NP5/6 was 3·0–5·5%, this large range being necessary in 1951 because of difference of opinion as to the optimum value. It has still not proved possible to narrow the range appreciably; in B.S.1477 : 1955 it is 3·5–5·5% magnesium. The mechanical properties specified for plate in the M condition are those of Lloyd's Tentative Requirements, that is 8·0/17·0/12 but an O condition has been added with properties 7·0/17·0/18. The only change in the other non-heat-treatable materials is that the properties of alloy NP4 have been adjusted in the light of experience.

With the heat-treatable alloys, HP10 has been deleted, and replaced by HP20 and HP30, both in the W and WP conditions. Alloy HP15–WP has also been discontinued, but HPC15–WP remains in the standard.

When a round standard test piece is turned from plate thicker than 0·499 in., which is permitted by the standard, the necessary machining removes all the cladding from clad plate; this has been recognised in the new standard by a requirement that such test pieces representing clad plate shall attain the proof stress and tensile strength of unclad plate, that is 1 ton/sq. in. higher.

The Future

Paradoxically enough, the issue of new or revised standards is an excellent stage at which to consider how they may be improved at the next revision. Progress is so rapid in industry generally, and particularly in the aluminium industry, and agreement on changes takes time to secure, so that thought must continuously be turned to the maintenance of standards. Criticisms will, no doubt, be levelled at the 1955 issue of B.S.1470–1477 and 1490, and the suggestions made will all receive serious attention as the foundation upon which possible amendments might be based.

A general complaint about aluminium alloys is their multiplicity, this is largely based on a misconception, since there are fewer standard aluminium alloys than, say, steels. Nevertheless, simplification is a subject which must receive unceasing attention, and where any alloy is no longer in general use it must be dropped from standards, as has been done in 1955, with, for example, alloys HR13, HF17, LM17 and LM19. On the other hand, new alloys or alloys of increased popularity must be provided for. No spectacular improvements in strength are to be expected in aluminium alloys; it must be realised that the strongest available, admittedly used principally in aircraft construction, can offer strengths over ten times as great as that of the pure metal, no mean achievement. But the addition of alloy H30 and LM21 provides examples of co-operative work resulting in a general advance in alloy formulation meriting standardisation, and this process can be expected to continue and demand recognition in future revisions.

As the world becomes smaller, international standardisation assumes even greater importance, and now that the International Standards Organisation is working actively on aluminium and its alloys, both wrought and cast, its decisions, agreed by member countries, will have inevitable effects on national standards, including those of the B.S.I. New methods of production may arise, requiring the standardisation of new wrought and cast forms. Inspection is an all-important handmaiden of standardisation, and new types of test are always under review, and may augment or replace those already specified in British Standards. Constant attention to production control may lead to a tightening of certain dimensional tolerances, but it is essential that close tolerances shall only be called for when advantage can be taken of them, since they inevitably increase production costs.

The aluminium industry is justifiably proud of the fact that it produces goods of high quality, and uses science and technology to the full. Its attitude to standardisation is the wise one that it must benefit both producer and user, and it is in this spirit that future revisions of the general engineering standards for aluminium and its alloys will be tackled, always through that essential arbiter, the British Standards Institution.

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6 Haughton, M. A. and Phillips, V. A., "A Survey of the Tensile and Bending Properties of Some Commercially Extruded Aluminium-Magnesium Silicide Alloys and Some Observations on Their Microstructures," Research Report A.1013, B.N.F.M.R.A., November, 1953, 18 pp.

THE address of the Sheffield branch of British Insulated Callender's Cables, Ltd., is now 87, Spital Hill, Sheffield, 4. The telephone number (Sheffield 24251) is unchanged.

New U.S. Metals and Ceramics Laboratory

View of the entrance to the new Metals and Ceramics Building at the American General Electric Research Laboratory.

THE modern trend towards speeding up research in industry has created a great demand for trained engineers, metallurgists, and chemists in most industrial countries, but in spite of almost universal recognition of the new importance of metallurgy and ceramics to scientific progress, the U.S.A. faces a serious shortage of young men and women trained in these fields.

The census of 1950 reported about 520,000 professional engineers in the U.S.A.: of these, only about 5% were working in metallurgy and mining. In the years since then, the picture has grown even less promising. The engineers graduating from school in 1953 included not 5%, but only 3·8% in metallurgy and mining. This represented only 900 new engineers in these fields—to serve a nation which, perhaps more than any other, draws its strength from its industrial plant, and builds that plant of metal. The 1954 graduating class saw the percentage fall to 3·1%; in 1955 it was 2·3%, and this year it is likely to be as low as 1·6%.

To fill a gap in education and research, a research facility destined to provide new materials for the future —for applications ranging from faster rockets and atomic power plants to labour-saving equipment—has been opened near New York. It is the new $5 million Metals and Ceramics Building of the American General Electric Company's Research Laboratory, which has been described as the world's most complete metals and ceramics processing laboratory.

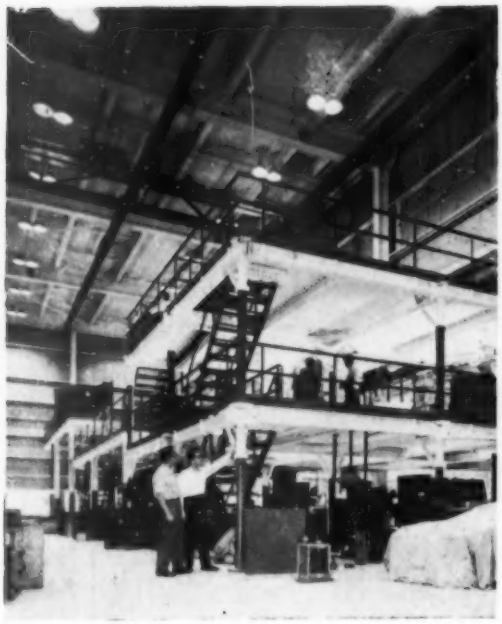
As part of the programme arranged in connection with the opening, some forty teachers of metallurgy and ceramics from leading U.S. universities participated in a conference at which problems of joint academic and industrial interest were discussed with American industrial leaders interested in the education and supply of young scientists. In connection with a later two-day seminar on melting and solidification, invitations were issued to about three hundred scientists and technologists.

The objectives of the huge new laboratory building at The Knolls, near Schenectady, New York, have been stated as :—

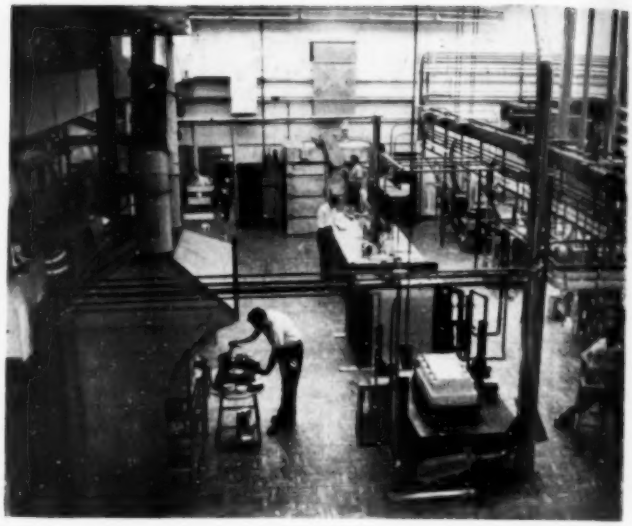
(1) To ascertain and analyse the fields of most critical need for materials and processes.
(2) To develop new processes for new businesses.
(3) To develop new materials to improve products.
(4) To study existing materials and obtain a better understanding of their properties and processing.
(5) To operate pilot plants and obtain economic data.

It has been pointed out that the organisation of the new Metals and Ceramics Building includes the establishment of a group of scientists to seek out and solve problems pertaining to materials and processes, wherever they may appear in the Company. Thus, in the new building, amid facilities of both laboratory and industrial size, the promising findings of groups of metallurgists, ceramists, physicists, and chemists will be applied to the kind of problems now creating a bottleneck at the designer's level.

The new building—which has more than 75,000 sq. ft. of floor space—seems more like a factory than a laboratory. Towering equipment, dramatic spark-showers from the huge furnaces, and the colour and motion inherent in the handling of red- and white-hot metals add to the effect. The G.E. top management had in mind that since ideas for new materials and processes frequently come from the "pencil and paper"



The "pilot-plant" feature requires rapid structural alterations.



Overall view of ceramic furnace area, with equipment used in sintering and melting ceramics.

and "test tube" work done in the basic research sections of the laboratory, much of the information which the Company's operating departments must know before they can take advantage of these new materials and processes can be learned only by trying them on a scale approaching actual industrial conditions. Thus, a building capable of doing this must necessarily be nearly factory-size. However, there is an obvious difference between this facility and a factory. Here both standard and specialised equipment is operated under laboratory conditions, with emphasis on measurement and control, and freedom from production schedules.

These pilot operations must also be of a transitory nature. Ideas do not come to the new building to stay—they are either sent forward for actual use or returned to the basic research scientists for further investigation. The building itself must be readily adaptable to the next project, and it has, therefore, an internal structure like an "erector set," permitting rapid assembly and easy alteration as a process is developed and perfected.

Ceramics Closely Allied to Metallurgy

Facilities for the study of ceramics have been placed side-by-side with those for metallurgy for two reasons. First is the tremendous importance of ceramic materials in the electrical industry, for insulators, lamps, radio and television equipment, and for other applications. Second is the fact that metallurgy and ceramics are closely allied fields, since both metals and ceramics are crystalline solids and the laws governing their behaviour are identical. It is thus important to make information developed in one field available to those working in the other. To maintain the maximum opportunity for scientific interchange, the ceramics facilities in the new building have been closely integrated with those of metallurgy. For instance, an extensive area for ceramics formulation, heat treatment, and testing adjoins a similar metal-treating area.

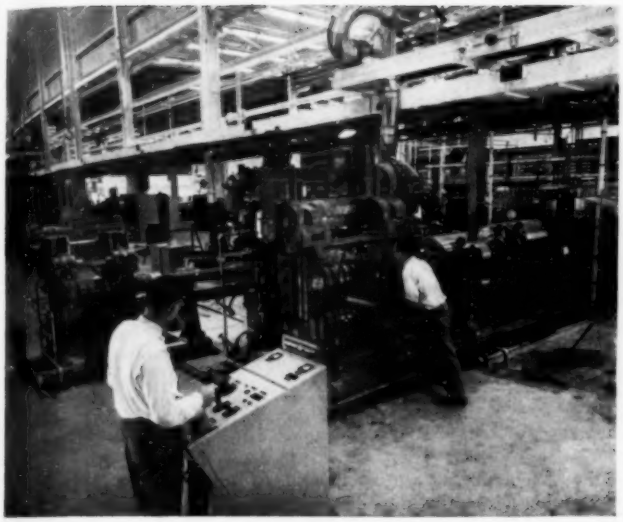
Each of the operations of the processes laboratory is headed by a member of the technical staff, who is assisted by metal-processors trained in skilled operations and by laboratory assistants who follow and guide the work. This arrangement places the responsibility for the work squarely on the shoulders of the scientists, and thus guarantees that the most comprehensive technical understanding is applied to every project.

Amongst other equipment, such as a large drop forge hammer, a planetary mill, a reversing mill and an extrusion press, a range of heat treatment furnaces is in operation in the new building.

Furnace Equipment

The furnace equipment has been supplied by the G.E. Industrial Heating Department, and a laboratory-type

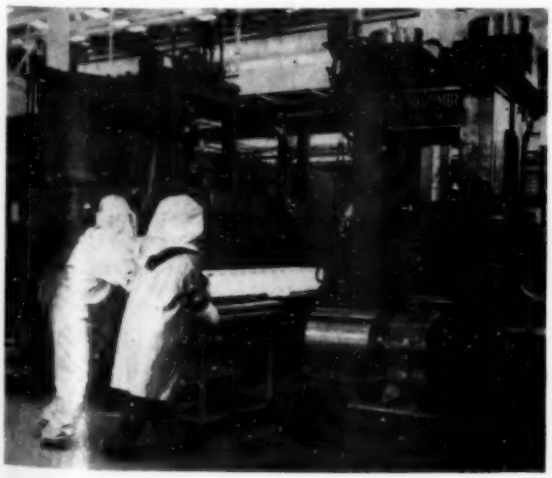
Metal being poured from a three-phase arc furnace.



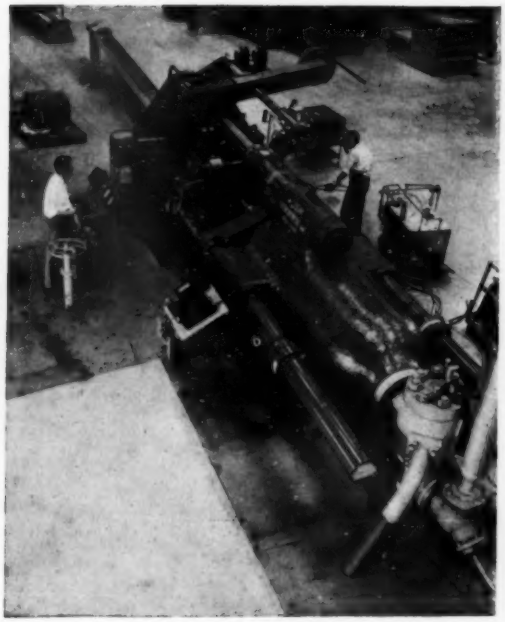
A heated bar is fed into the high speed mill whose drive permits reversal in 1½ seconds.

box furnace with molybdenum heating units for operation at 2,912° F. (1,600° C.) is the largest of its type ever built by the Company. It will heat two stainless steel billets, each 8 × 8 × 36 in., weighing 600 lb., in one load. A mechanical fixture is used to load the work to prevent damaging the furnace components, which are extremely fragile at this high operating temperature. Thus, the door opening must be 24 × 16 in. to accommodate both the load and the loader. A pure hydrogen atmosphere is used in the furnace to protect the molybdenum heating units from oxidation. An automatic, high-velocity flame curtain is used to keep the air from entering the furnace chamber when the door is opened.

The furnace, which is rated at 110 kW., is fed by a 220 V. three-phase supply. It employs a refractory hearth and G.E. Reactrol system. The furnace and associated power system and instrument panel are portable: each component is unitised and equipped



Planetary mill for hot rolling.



The 1,250-ton extrusion press can extrude experimental high temperature alloys.

with lifting hooks. The furnace weighs about 10 tons, and the entire system can be moved by the laboratory's 10-ton crane and put into operation in another location within an eight-hour period.

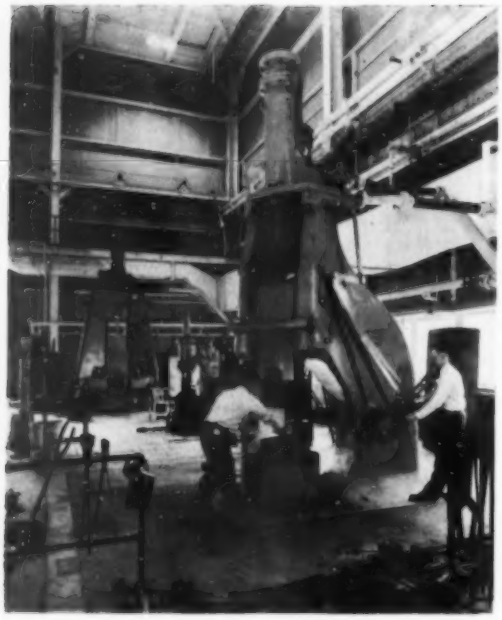
A laboratory-type box furnace, equipped with Globar heating units and designed to operate at 2,200° F. (1,204° C.), is rated 150 kW., and is fed by a 78 V. single-phase supply. It has three separately controlled heat zones, and is equipped with G.E. Reactrol system and instrument panel. The door opening is 31 × 24 in. and the furnace is used with a pure hydrogen protective atmosphere. A small laboratory-type box furnace with molybdenum heating elements has a door opening of 4 × 4½ in. This unit is rated 20 kW., the supply being 440 V. three-phase, and the operating temperature is 3,100° F. (1,704° C.). It is equipped with G.E. Reactrol system.

A 440 V. three-phase continuous strip annealing furnace, which can easily be converted from a mesh-belt to a catenary furnace, is equipped with Globar heating elements and is rated 52 kW. A hydrogen atmosphere is used in this furnace. There is also a 15 kW. high frequency induction heater.

Rectifier Drive for Reversing Mill

The reversing rod and bar mill in the Metallurgical Building is believed to be the first reversing rolling mill in the United States equipped with a rectifier drive. This was installed in order to make possible the assessment of the economics of rectifiers versus motor-generator sets for small reversing mills. Experience in building reversing rectifier equipment was also considered a necessity.

The drive is arranged to act as an invertor as well as a rectifier, so that it can accept pumpback current from the mill motor during reversal. Fast reversal is also provided by the rectifier drive—a necessity when rolling



2,500-lb forging hammer for hot-working large ingots.

hot metal. Reversal from top speed in one direction to top speed in the opposite direction in two seconds has been demonstrated.

The rectifier is controlled by a voltage regulator arranged to provide five speed points in each direction. In addition, a creep speed for uniform roll cooling is provided. The voltage regulator consists of a power amplistat for supplying saturating current to the rectifier phase shift reactor and two pre-amplifier amplistats. Thus the drive equipment with the voltage regulator is made up of static components. The auxiliary D.C. required is supplied by a metallic rectifier.

The rectifier drive uses armature reversing contactors to change the polarity of the rectifier with respect to the motor. During reversal, the armature contactors must reverse at the correct time, and must reverse quickly for fast motor reversal. These contactors are controlled by three additional amplistats.

The drive motor for the mill is a mill auxiliary-type motor which has a nominal rating of 250 h.p., 375 r.p.m., at 230 V. D.C. However, motors of this type are suitable for operation at higher voltages, with a corresponding increase in horsepower and speed. In this case, the motor is operated up to 550 V. D.C., and at that voltage has a rating of 630 h.p., 925 r.p.m. Since the motor can operate above its base speed of 375 r.p.m. by voltage increase, the whole speed range is obtained by voltage change, and is, therefore, at constant torque.

The rectifier consists of phase-controlled, sealed-tube ignitron rectifier units. The overload characteristics of the rectifier are matched to the motor characteristics, so that it can supply power to the motor within the motor's commutating ability.

Research Problems to be Solved

During the opening ceremonies in November last year, the growing importance of research in metallurgy and ceramics was stressed by several speakers. All of them believe that the addition of the new $5 million building to existing facilities at The Knolls, gives G.E. scientists one of the world's finest laboratories for seeking new knowledge and translating it into new materials and processes.

"A renaissance" is what Dr. C. G. Suits, G.E. Vice-President and Director of Research, called the ever-increasing interest of scientists in the structure, properties and applications of metal and ceramic materials in his opening address.

"In its beginning, the art of metallurgy lifted men from the Stone Age to the Age of Metals. As their skills increased, men learned how to use a variety of metals: copper, iron, steel, aluminium, and a handful of alloying metals like zinc and tin. To these artisans belongs much of the credit for the Industrial Revolution and the present level of technical progress.

"In recent years, however, man's inventive brain has begun to out-run the available materials. In chemistry, electronics, aviation, and atomic energy, needs have developed which the old metals cannot meet, and it seems that in a dozen critical fields metallurgy has fallen behind the demands of industry for new and better alloys.

"Facing extraordinary conditions during the first attempts to make an atomic bomb—from heat and corrosion as well as atomic radiation—the metallurgists and ceramists have since been forced into a research programme of unparalleled scope and complexity. The American Iron and Steel Institute says, "A second Age of Metals is upon us, shaping the world we will live in. New metals and alloys are opening up entirely new technologies and extending the frontiers of the old. Familiar metals are being investigated from fresh directions. Scarce metals, heretofore used merely as alloying elements in steel, are now being investigated as base metals themselves. Rare metals are being prised loose from their ores in quantities, and some metals that were mere laboratory curiosities are now being considered commercially.

At the same time, ceramists are applying similar knowledge and techniques to their work. The result is being felt not only in the production of versatile new ceramic materials but also—thanks to side-by-side work with metallurgists—in the exciting area of "cermets" where metals and ceramics are combined."

American Electric Steel Capacity

CONSIDERABLE expansions in the American steel industry are foreshadowed by the news that in recent weeks orders have been placed for over a dozen electric arc melting furnaces, each of more than a hundred short tons capacity. Of these, the majority are to be built by the Pittsburgh Lectromelt Furnace Corporation, whose licensees in this country are Birlec, Ltd., Birmingham.

Uranium Rolling Mill for Sweden

AN order for a specialised mill for rolling uranium has been placed by A.B. Atom Energi (the Swedish Atomic Energy Authority) with the Tube Investments subsidiary, W. H. A. Robertson & Co., Ltd., of Bedford. Robertsons built the first specialised mill of this type in the United Kingdom, and now have a number in production for the U.K.A.E.A.

Electrical Plant for the Metal Industries

Progress in 1955 Reported

The General Electric Co. Ltd.

Rolling Mills

From the Australian Iron and Steel Co., Ltd., a contract has been received for the electrical drive for a 2-stand temper mill similar to those in service at Trostre. Each stand will be driven by a 1,250 h.p. D.C. motor, and six motors, representing a further 2,100 h.p., will serve to drive the coilers and uncoilers. Control exciters, operating in conjunction with a Ward-Leonard system, will be used to provide the rapid response and complete stability on which the efficient operation of high-speed mills of this type depends.

In connection with the conversion of an existing 5-stand finishing mill to a 7-stand mill at the Hawarden Bridge Steelworks of John Summers & Sons, Ltd., a large amount of electrical equipment is involved, including D.C. motors for the main drives of three of the stands, a 10,000 kW. grid-controlled rectifier equipment and all the associated control gear. Each of the stand motors is rated at 4,000 h.p., 540 volt, with a speed range of 180/360 r.p.m.

At the Margam Works of the Steel Company of Wales, the 74 in. × $\frac{3}{8}$ in. cold cut-up line is now in full production. It is the first of its type to be commissioned in this country, and is designed to cut strip from 20 ton coils automatically into lengths varying from 4 ft. to 36 ft., and to pile the cut lengths. The maximum speed of operation when cutting $\frac{3}{8}$ in. metal is 150 ft./min., rising to 250 ft./min. for $\frac{1}{16}$ in. strip. The equipment includes a 5-machine motor-generator set, 9 force-ventilated D.C. motors totalling more than 700 h.p., and all the associated control gear. Rapid speed response combined with stability is assured by the use of control exciters for the motor-generator set, and for current control of the mandrel drive.

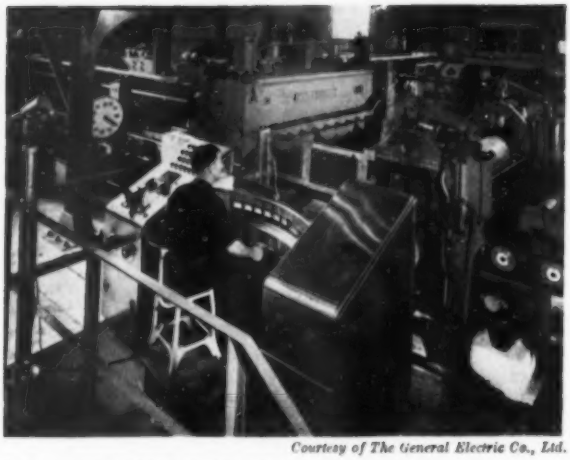
A recent contract placed by the Steel Company of Wales covers all the electrical equipment for two continuous electrolytic tinning lines to be installed at the Velindre Works. These lines will be capable of running at 250-1,250 ft./min., and the electrical equipment for each will include a 510 h.p. main Ward-Leonard set, three auxiliary motor generators comprising exciters, boosters and the high-frequency control alternators, some 50 motors, and all associated switchgear. Very precise relative speed control of the motors along the line and accurate tension control are essential features of the installation. The Ward-Leonard set, operating in conjunction with electronic and magnetic amplifiers, provides the main speed control, while 50-cycle magnetic amplifiers are used in the control of the coiler and uncoiler. For maintaining constant tension, 400-cycle magnetic amplifiers operate in conjunction with tension control boosters. Loop control of the strip between entry and processing sections of the line is achieved by means of photo-electric equipment. All the electronic and magnetic amplifiers are accomodated in the main contactor board, which is about 90 ft. long.

The order placed by Davy and United Engineering Co., Ltd., on behalf of the Broken Hill Pty. Co., Ltd., Australia, for the electrical equipment for an ingot buggy is of special interest. The buggy, which transports hot ingots from the soaking pits to the rolling mill, is operated by two winch motors which serve to reel-up or pay-out the haulage rope according to the direction of travel of the buggy. These motors are fed in parallel from a Ward-Leonard set, operating in conjunction with control exciters to give precise speed and tension control. The pay-out motor is driven by the tension in the haulage rope and thus acts as a generator to feed power back to the supply. The tension in the haulage rope is maintained by means of a series booster.

The operation of the equipment is completely automatic, the buggy proceeding to any of ten stopping positions as selected by the operation of the appropriate push button on the control desk. Acceleration and deceleration are controlled automatically according to the distance the buggy has to travel. It will stop at the selected

Six Pennsylvania Dixie mills at the Appleby Frodingham Steel Company.

Courtesy of The General Electric Co., Ltd.



Courtesy of The General Electric Co., Ltd.

The up-cut shear in the 74 in. × ¾ in. cold cut-up line at the Margam Works of the Steel Company of Wales.

soaking pit, even if travelling at full speed in the opposite direction when the selected push button is operated. Provision is also made for manual speed control from the desk.

Electronic Control

It is often essential to provide for close matching of speeds of driving motors, and for this purpose a robust type of relay has been developed. Its operation depends on the difference between two voltage signals, and the equipment is designed to initiate the appropriate speed correction if this difference exceeds 2% of the maximum value of the signal.

At the Brierley Hill Works of Richard Thomas & Baldwins, an electronic device is used to prevent lateral movement of steel strip when reeling. The faces of the coils must be kept as flat as possible, as any unevenness would be likely to give rise to defects which would interfere with the subsequent processing of the metal. Any displacement of the strip is rectified by a tilting roller, the driving motor of which is arranged for Ward-Leonard control. The Ward-Leonard generator is excited by thyratrons, under the control of a photo-electric cell which detects any lateral movement of the strip. In operation this equipment has achieved an accuracy of ± 0·01 in.

Ore Handling and Dressing Equipment

A contract has been received from Colvilles, Ltd., for its General Terminus Quay installation, which is an essential link in the supply of iron ore to the Company's new Ravenscraig Works at Motherwell as well as to Clyde Iron Works. The plant is located in the Glasgow dock area, where ore-carrying ships will discharge direct on to conveyors, delivering to overhead bunkers of some 14,000 tons capacity. Scale cars running beneath these bins will transfer weighed amounts of ore to a series of smaller bunkers immediately below the main storage bunkers. The purpose of this is to enable a complete train of ore wagons, each of 35 tons capacity, to be loaded in one operation, and to maintain the essential supply of ore to the works, while keeping the considerable amount of traffic within the capacity of the rail link between docks and works.

Advantages to be gained from the blending of iron ore are becoming widely appreciated, and a contract has been received from Ilva Alti Forni E Acciaierie D'Italia of Genoa, the largest producer of steel in Italy, for an ore blending and reclaiming plant which will be the first installation of its kind in that country. The plant is designed to feed ore into four blending piles, each of a capacity of 11,900 metric tons, at the rate of 400 tons/hr.

Development work has continued on a number of items. The Robins-Messiter reclaiming machine has been redesigned and simplified so that, without any sacrifice of efficiency, the cost of both the machine and its foundations has been reduced. Designs have been completed for a new wagon marshalling system, whereby manpower is cut down on tippler installations.

Mineral Dressing

Development work in mineral dressing over the past twelve months has largely been concerned with heavy medium separation, which is frequently carried out in a conical vessel containing the heavy medium. Because economic factors prohibit the removal of pieces bigger than about 2½ in. by present methods, a new type of separation vessel has been developed and is being subjected to exhaustive tests.

Another field of exploration is electrostatic separation, and a commercial high voltage separator has now reached the drawing board stage : this will be of the earthed roller type. A variety of minerals can be separated with a high feed rate and very low power consumption, the basis of separation being surface conductivity. Particle size range will depend to some extent on the minerals being separated, but 1 mm. is roughly the upper limit, while any significant quantity of minus 200 mesh material will cause serious reduction in capacity.

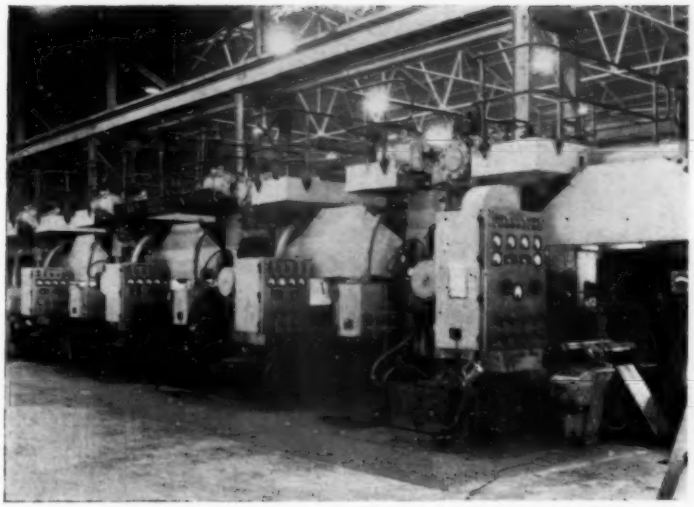
An order has recently been received from the Appleby-Frodingham Steel Company for a seventh Dixie moving breaker plate hammer mill for use in the Company's new ore crushing plant. An interesting development in this connection is the receipt of an enquiry from the Frankfurt firm of Lurgi for four similar machines in connection with steelworks in which they are interested.

During the period under review, a dust collection and precipitation plant has been put into operation at The Steel Company of Wales, where coke dust from the screening plant is being handled. The equipment is capable of precipitating particles of dust down to 5 micron and less in mean diameter.

Metropolitan-Vickers Electrical Co., Ltd.

Rolling Mills

During the year, orders have been received for many main and auxiliary rolling mill drives. One of exceptional interest covers equipment for a new alloy bar and rod mill for Samuel Fox & Co., Ltd. The output will range from 2½ in. diameter down to 5 gauge rod, the latter being finished at speeds exceeding 40 m.p.h. in the case of stainless steel. The first three stands will be driven by a 1,500 h.p. A.C. motor, and the remaining fifteen by D.C. variable speed motors (four of 200 h.p., five of 350 h.p., and six of 250 h.p.) supplied by mercury-arc rectifiers. Both bar and rod mills will be equipped with a servo system using flux-resetting magnetic amplifiers. In the bar mill the control operates on the main motor fields ; this will be backed up by voltage regulation by



A tandem cold strip mill driven by four 1,000 h.p. D.C. motors at the Whitehead Iron and Steel Company's Works.

Courtesy of Metropolitan-Vickers Electrical Co., Ltd.

static amplifiers on the rectifiers supplying the group busbar, and by Brentford regulators on the input sides of the rectifier transformers, servo operated so as to maintain the optimum phase-shift on the rectifier grids. On the rod mill, where transient and steady-state speed changes are more critical, there is a separate transformer and rectifier for each motor, and the speed control servo system operates on the grids of the individual rectifiers; a closed-loop current control magnetic amplifier servo on each motor field prevents the speed control from going outside the range of the rectifier grid control. Manual control of the motor speeds is effected by small induction regulators, whose rectified output controls the amplifiers; the use of flexible tails for the regulator rotor connections eliminates sliding contacts from the control system.

A large twin-drive blooming mill equipment soon to be installed at Dorman Long's Cleveland Works, will comprise two 2,500 h.p. 40/90 r.p.m. D.C. motors with flywheel motor-generator set and high-response control equipment. Work is also well advanced on the universal beam mill at the same Company's Lackenby Works. This will have three 8,000 h.p. 65/160 r.p.m. double armature D.C. motors for the main mill and four 1,350 h.p. 125/310 r.p.m. motors for twin-motor drives, all the motors being supplied from three flywheel motor-generator sets.

Several equipments for foil mills have been ordered, including drives for two new mills in a Midland works where an installation has been commissioned with seven single stands with Ward-Leonard drive from motors ranging from 135 to 170 h.p. Another recent order covers the drive for a mill which will roll 36 in. wide foil at speeds up to 3,000 ft./min.

A new skin pass mill for stainless steel commissioned in the Sheffield area has a 300 h.p. main drive and two 164 h.p. reel drives, and a skin pass mill at Richard Thomas & Baldwins, Ebbw Vale, is being modified to provide more accurate control over a greater tension range than was possible when it was built in 1937. A single-stand mill with coiling reel in the Midlands has been converted into a 2-stand tandem mill, using an existing motor and Ward-Leonard set for the additional stand.

A three-stage reconstruction scheme for a rod mill began with the electrification of four laying reels. The second stage—due to be completed this year—involves D.C. motors totalling 3,000 h.p. for the roughing, intermediate and finishing mills, together with the necessary control gear and additional mercury-arc rectifier capacity.

Finishing Lines

The largest pickle line in Britain, shortly to be commissioned, is designed to process steel strip up to 74 in. wide after leaving the hot strip mill in the Abbey Works of the Steel Company of Wales. The catenary in the pickling tank is controlled by means of transductors instead of "dancing rollers" for the first time in this country: the transductors built into the brickwork at the bottom of the tank sense the proximity of the strip, and their output is used to control the speed of the pinch rolls via a magnetic amplifier and metadyne amplifier and booster.

Two electrolytic cleaning lines for finishing steel strip will be commissioned next year at the Steel Company of Wales Velindre Works, each powered by a 100 kW. uncoiler motor, 60 4½ h.p. geared motors for the tank group, two pinch-roll motors, and a 300 h.p. coiler motor—all supplied by a 300 kW. 300 V. generator with boosters for the various groups. On two pickle lines at Ebbw Vale, the electrical equipment installed in 1937 has been modified in order to speed up production, and equipment has been ordered for a third pickle line to handle sheet up to 54 in. wide and 0·145 in. thick with a maximum coil weight of 12,000 lb. This line will be driven by D.C. motors totalling 1,200 h.p., which are divided into three groups, each with its own motor-generator set. Looping pits at each end of the tank group will allow the strip to be sheared, welded and stitched without slowing down the sheet in the tanks, photo-electric control at the exit end holding the loop size constant.

Electrical equipment ordered for a new 54 in. strip cut-up line, includes photo-electric loop control. In the

Courtesy of Metropolitan-Vickers Electrical Co., Ltd.

A Head Wrightson scale car with M-V electrical equipment.

classifier section the speed differential required between belts for good shingling and piling varies owing to the effects of friction at different speeds, and to overcome difficulties during acceleration from rest and when changing line speeds, automatic control will be provided.

A Morgan flying billet shear has been equipped with photo-electric control, and the cut is now made at speeds up to 650 ft./min. with an accuracy of less than $\frac{1}{4}$ in. on lengths of 15–30 ft. The control works in conjunction with a metadyne-controlled Ward-Leonard generator supplying the four 180 h.p. driving motors, the photo-cell being mounted on a motor-operated traversing carriage situated on the controller table after the shear. A billet-length monitor designed to indicate in inches the error in length of cut metal after leaving the shear has been installed in another works. By intelligent reading and alteration of the shear speed the operator can minimise the error, but later automatic correction will be obtained by feeding back the measured error into the shear control equipment.

Blast Furnace Hoist Equipment

A 125 h.p. blast furnace hoist will be equipped with Ward-Leonard automatic control and a 24 in. solenoid operated brake acting on the winder drum. When the skips are started, the small bell opens, dumps its load on the large bell and closes. As the loaded skip reaches the top of its travel, it is mechanically tipped, and after a 5 sec. delay to allow time for it to empty, the distributor turns in accordance with the setting of a load angle selector switch, the control allowing up to six loads per angle. If the small bell has not sealed by the time the load reaches the top of the hoist, the skip waits, and the bell " jigs " if it has not sealed by a certain time. The large bell operates after a predetermined number of loads (up to six). The two bells are interlocked so that they cannot open at the same time. The sounding rods are automatically withdrawn before the main bell is lowered. Two similar hoist equipments have been installed during the year.

Drawbenches

Electrical equipment has been ordered for two large drawbenches rated at 100,000 lb. pull at the die. One is for drawing single tubes at speeds of 87 and 130 ft./min., and will have a 450–300 h.p. slipring induction motor drive, and the other, which is capable of drawing three tubes at once at speeds varying from 150–300 ft./min., will be equipped with a 550 h.p. D.C. shunt wound motor with a 300–900 r.p.m. speed range.

Other orders include several equipments for multi-block wire drawing machines required for the reconstruction of a Midlands wire mill; they aggregate about 250 h.p., all with automatic control. Motors and automatic control equipment have also been ordered for a tube bending machine which produces lengths of tube to preset dimensions from straight stock.

Induction Heating

A radio-frequency plant incorporating a furnace suitable for melting a 5 lb. charge of steel has been despatched to Australia for use in the laboratories at Newcastle University College, N.S.W., the equipment having been designed for instructional use, and three installations for melting or heating special materials have been commissioned at various establishments of the U.K. Atomic Energy Authority.

To meet modern operating conditions, a new range of H.F. motor-generator sets have been developed with power outputs of 100–300 kW. at 2 kc./s., and 100–200 kW. at 10 kc./s. The rotors of both motor and generator are mounted on a common shaft, with ball-location and roller bearings of the constant level oil lubricated type.

Welding

The use of automatic welding continues to expand, and designs are in hand for a smaller and more compact welding head for the submerged arc process, and for simplifying the arc control circuit. Two types of flux have also been introduced, one for high current welding and the other for welding at high travel speeds on thin material. Interesting developments have also taken place in automatic welding in the argon arc and atomic hydrogen fields, whilst new electrodes for metallic arc welding include a very fast contact electrode for mild steel and a low-hydrogen electrode.

Resistance welding machines continue in steady demand and several special roller-spot and condenser discharge spot welders have been supplied to the aircraft and automobile industries—also a large automatic machine for flash-butt welding lorry axle cases.

Miscellaneous

Steelworks Cars.—Orders have been received for a further two sets of electrical equipment for Head Wrightson steelworks cars, seven sets having been delivered. Five sets of motors have also been ordered for cars by Ashmore, Benson, Pease & Co., Ltd.

Mercury Arc Rectifiers.—An important order has been received covering 1,540 kW. and 1,000 kW. grid-controlled mercury arc rectifiers of the pumpless steel-tank type, several 200 kW. grid-controlled units, and a 1,000 kW. free-firing unit. These units will supply variable speed D.C. motors in a rolling mill installation at the Stocksbridge works of Samuel Fox & Co., Ltd., which is to produce high quality steel bars and rods.

The Mains Frequency Coreless Induction Melting Furnace

Practical Considerations and Applications

An announcement was made last year concerning an agreement which had been made between Otto Junker, G.m.b.H., of Lammersdorf, Germany, Ajax Engineering Corporation of Trenton, New Jersey, U.S.A., and Birlec, Ltd., of Birmingham, whereby mains frequency coreless induction furnaces would jointly be developed. Shortly afterwards, Birlec, Ltd., organised a series of meetings, in Sheffield, Birmingham and London, so that interested companies could learn more of the potentialities of this type of furnace. This second part of the report of the proceedings, dealing with applications of the mains frequency furnace, has been prepared from the lecture given by Dr. K. Scherzer, of Otto Junker, and the ensuing discussion.

THE first call for a mains frequency coreless induction melting furnace came from a firm engaged in the melting of light alloy scrap. The idea was to build a furnace in which heavy stirring of the bath would take place. It was soon found that such a furnace could profitably be used for melting small scrap, such as borings and chips, because the heavy stirring washed the chips down into the bath before they had a chance to be oxidised.

The next move came from the iron foundries, and especially from the machine tool foundries, who hated the idea of selling 100 tons or so of cast iron borings per month at a very low price, and buying the same amount of pig iron at about five times the price. They wished to use the mains frequency furnace for melting 100% borings and swarf.

These two are the main fields of operation of the mains frequency coreless induction furnace at present, although units have been designed and operated successfully for melting steel, copper-base alloys, and—with an iron crucible—magnesium. Of the Junker installations in operation—nearing a hundred—some 65% are melting cast iron, 25% light metals, and 5% each steel and copper-base alloys.

This furnace will certainly not replace entirely the existing types of electric furnace. It is not expected, for instance, that it will replace the ordinary channel type induction furnace for melting standard brass alloys, except, perhaps, when very large quantities of borings and swarf have to be melted. The coreless type is to be preferred in cases where the channel is liable to break up or become obstructed due to high temperature operation or the effect of the molten metal on available refractories.

Comparison with H.F. Furnace

The fields of application of the mains frequency and high frequency furnaces are similar, but not identical, and the question of cost is an important consideration in making a choice between them. For furnaces of given output, the capital cost is in favour of the mains frequency furnace, rough figures for a 15–18 cwt. furnace of this type, powered at 400 kW., being £15,000 as compared with £25,000 for an equivalent high frequency unit having the same melting rate and powered at about 400 kW. With a high frequency unit a frequency changer is necessary: this may consist of a motor, a generator, and a regulator. The power factor of the high frequency furnace is lower than the corresponding mains frequency furnace, so more capacitors are necessary. High frequency capacitors are cheaper, but the greater number required probably balance the cost as compared with a mains frequency capacitor bank, which may represent 40–60% of the total capital outlay. On top of this there is the cost of the motor generator set, and the slight loss of efficiency resulting from the use of a frequency changer. Even when an invertor unit—which is cheaper than a motor generator set and dispenses with capacitors—is used as the frequency changer the capital outlay still exceeds that for a mains frequency unit.

There is little evidence available on the energy consumption of the two types of furnace melting under similar conditions, but there does not appear to be a great difference between the two. Figures of 750–800 kWh./ton in melting steel by the high frequency process compare with 720–760 kWh./ton in a mains frequency furnace. It is not possible to make accurate comparison of such figures, however, without details of factors such as idle time, superheating temperature, holding time, refining time, etc.

One of the limitations of the mains frequency furnace is the amount of power that can be put into the charge without causing excessive stirring. This means, in effect, that the maximum possible melting rate of a mains frequency furnace will be lower than could be achieved with the same size high frequency unit. The former type of furnace represents a compromise between capital cost and production rate.

There is insufficient information available to assess the advantages conferred by the stirring action of the mains frequency furnace in the melting of highly alloyed steel, where very refractory materials have to be introduced into the melt and uniformly dispersed. No difference has been found in the quality of steel made by the two types of furnace, nor does the increased stirring appear to affect the inclusion count. For the same applications, the same lining life is achieved as in the high frequency furnace. A hair crack in the latter type of furnace is much more dangerous than in the mains frequency type, as will be explained later.

1,000 kW. coreless mains frequency induction furnace of 8 tons capacity pouring cast iron for rolls.

Comparison with Arc Furnace

For the same melting rate there is probably little to choose between the cost of direct arc and mains frequency induction furnaces, but in comparing the two types, the question of power input must be taken into consideration. The aim of most arc furnace operators is rapid melting, and whilst the rating of a 3 ton mains frequency furnace would be limited to about 750 kW., an arc furnace of the same capacity would probably have at least 1,200 kVA. An arc furnace of 3 tons capacity rated at 1,500 kVA. would run out at about £22,000, whilst the cost of a 3 ton mains frequency furnace rated at 750 kW. would be of the order of £18,000. The difference in the capital costs would, however, be offset by the difference in production rates.

In one respect the mains frequency furnace has a decided advantage over the arc furnace, and that is in the quality of the labour required for its operation. The arc furnace calls for skilled operators, whereas, with the mains frequency furnace they can be dispensed with, as has been done at the Junker works.

General Operating Factors

Although some mains frequency units operate continuously at full load, it is more usual to use a tap transformer capable of giving 25%, 50% and 100% of full power: there is also an extra tapping giving 125% for starting up. This does not mean that the actual maximum rating is exceeded, but that a higher voltage is used at the start, when the full load cannot be taken because the furnace is not full of liquid metal. From about half full the furnace runs on full power. Temperature control is achieved by means of the tapped transformer. For a furnace rated at 1,000 kW. the rating of the mains transformer supplying it would be of the order of 1,100 kVA. with the second method* of static balancing. With the first method the kVA. would be even greater, as the power factor is 0·85 as against 0·9 for the second method.

The whole success of this furnace has been due to the fact that it was designed as a single phase furnace with a very good static balancer in front of it. The coil could not be made suitable for three-phase operation without sacrificing power factor and efficiency. On the score of efficiency the energy consumption would go up, and on the score of power factor the amount of additional capacity required would increase the capital cost.

Because the heating is more effective with large pieces of solid metal, it is better, when starting with a cold furnace and an empty crucible, to use such material for the first charge, smaller scrap and borings being added to the molten bath.

Cast Iron Melting

As was mentioned earlier, a number of furnaces have been installed for melting cast iron, the biggest to date having a capacity of 8 tons and a rating of 1,000 kW. In this unit, 3 tons of borings can be put into the furnace at a time and melted down in an hour. The smallest unit Junker make is an 800 kg. furnace rated at 300 kW., one of these being used in the makers works for producing special cast iron for the motor industry.

A somewhat unusual installation was called for by a firm having limited power available, but wanting a furnace which would give 6 tons of liquid iron, in which borings could be melted to the full capacity. As stirring to the top level of the bath is not possible, the coil is arranged with three sections, the top two in operation at the beginning and the bottom two at the end.

The mains frequency furnace has been adopted for melting cast iron for two main reasons, concerned with economics and quality. Because it can be used to melt borings and swarf rather than pig iron and heavy scrap, it can produce molten iron more cheaply than the cupola. One firm producing spheroidal graphite iron has found that when melting from cold it can bring the total cost of liquid iron down by £10 a ton. In another case it was found that the cost of liquid iron coming from the cupola amounts to £25 a ton, compared with £17 a ton melting cost from the electric furnace.

The energy consumption, when melting cast iron up to the normal melting temperature of 1,250° C., is about 500–540 kWh./ton. If it is desired to raise the temperature to 1,450–1,500° C., another 100 kWh./ton are required, bringing the total to 600–650 kWh./ton.

Apart from melting cast iron, the mains frequency induction furnace can be used for making cast iron by melting steel and adding carbon and silicon. One Berlin firm is able to obtain large quantities of transformer sheet scrap, and has based the whole of its cast iron production on this material, carbon being added in the form of crushed electrodes. This results in a very high quality iron which is very low in sulphur: where a high sulphur is required for some reason or other, coke can be used for recarburising. Spheroidal graphite iron has been successfully made in the mains frequency furnace, and a firm using a 3 ton unit for melting malleable iron has been able to reduce the annealing time from 90 hours to 50 hours.

Steel Melting

As has been mentioned earlier, the mains frequency induction furnace has not been so widely applied to steel melting as it has to cast iron, but there have been a number of units installed for this purpose. One of the first firms to install a high frequency furnace 25 years ago has ordered two 16 cwt. furnaces after a long series of tests and melting experiments in the Junker foundry.

Plain carbon steel can be melted in this type of furnace, but its main application is in the production of alloy steels. The first stage is, in many cases, the melting of plain carbon steel scrap, followed by the addition of

* This may appear to be at variance with the earlier statement that for efficient operation the charge should consist of pieces 8 in. in diameter. Large pieces are used for the initial melt and borings are then added to the bath.

alloying materials. There are possibilities of carrying out refining operations in the furnace and reference will be made later to the experimental work in progress and projected.

The energy consumption figures for steel vary between 620 and 760 kWh./ton, the value depending on the conditions.

Light Alloy Melting

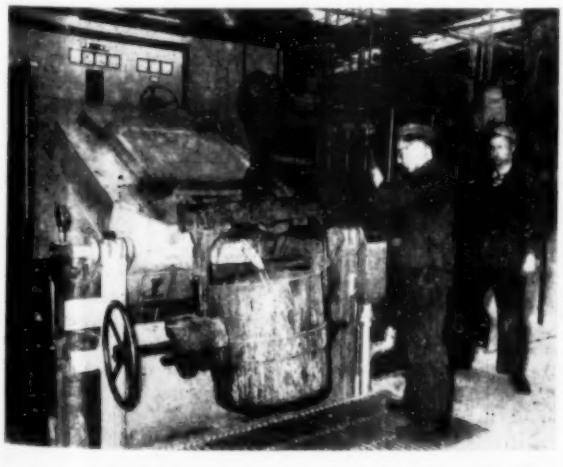
After cast iron, the light alloys represent the biggest melting application of the mains frequency induction furnace. For light metals plants have been built from 600 kg. to 3 tons capacity, and have been used for melting both cast and wrought alloys. Customers are tending more and more to ask for heavy stirring in the melting unit, and although operations such as cleaning and treatment with chlorine or nitrogen can be carried out in the furnace with reduced stirring, it is not then used to the best advantage. There is less danger of overheating than in the channel type furnace where the heat is developed only in the channel. Lining life of the mains frequency furnace in the light alloy field is indefinite, as no unit has yet been taken out of operation because of the breakdown of the lining.

A large Swiss aluminium company is using a 3 ton furnace—with a rating of 600 kW. and giving an output of 1 ton/hr.—for the melting of wrought light alloys. Better figures can be obtained with a channel type furnace, but only on the basis of 24 hours a day working.

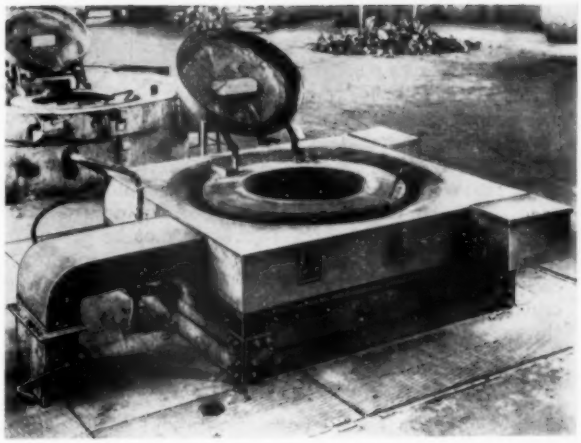
A furnace of 1½ tons capacity has been installed for the melting of alloys containing 6–24% silicon, and it has been found that such a high percentage of silicon is melted successfully in this type of furnace. A furnace of special interest is one installed in a French automobile works for melting either cast iron or aluminium alloys.

Units for melting magnesium are built with capacities from 150 kg. to 2 tons, and steel crucibles are used, pouring being effected by tilting the furnace or removing the crucible.

The energy requirement for melting aluminium alloys is in the region of 540–560 kWh./ton for a melting temperature of 720° C. In another case an average taken over a year worked out at 580 kWh./ton. For magnesium small units of 150 kg. capacity require 600 kWh./ton and large units 500 kWh./ton.



240 kW. coreless mains frequency induction furnace of 800 kg. capacity, melting aluminium at 400 kg./hr.



90 kW. coreless mains frequency induction furnace of 150 kg. capacity. In its iron crucible magnesium can be melted at 150 kg./hr.

Melting Copper Alloy

For copper alloys, furnaces ranging in size from 10 cwt. to 3 tons capacity have been designed. They are mostly used for copper-nickel, bronze, and brass alloys, where a large amount of swarf has to be melted, or when intermittent operation is desired. Whereas a 20 ton mains frequency furnace can be designed for cast iron, there is some doubt about the lining in a furnace of such size melting copper alloys.

The energy requirements for copper alloys range between 280 and 450 kWh./ton, which is quite high. Although the figures may be higher than in the channel type of furnace, the mains frequency unit is advantageous where only one or two melts are to be made in an alloy. When melting special bronzes, difficulties are likely to be encountered with the channel type furnace, due to higher temperatures, segregation tendencies, and the need to run the furnace continuously. Not only has the mains frequency coreless furnace been used to melt borings, but metal grinding dust from a foundry casting ships' propellers has been dealt with successfully. A salt layer was used because the amount of bakelite mixed with the metal dust was so high that without a salt flux the dust would coagulate.

Refractories

A lining of refractory material rammed down between a former and the coil is used, as in the high frequency furnace. There is also a certain amount of asbestos and micanite insulation between the coil and the ramming material. The thickness of the crucible is usually between 3 and 4 in., depending on the material to be melted and the hydrostatic pressure exerted by the bath. When melting cast iron, the life of the bath has been found satisfactory up to very high temperatures; the normal is about 150 heats when using a pouring temperature nearing 1,500° C. With steel, any number between

30 and 150 heats may be obtained from a lining, depending on the treatment of the crucible, the working of the slag, and the care with which repairs are executed.

Nearly all linings are applied in a dry state, so that melting can begin immediately after ramming. For low melting point metals, there is a certain difficulty in reaching the sintering temperature of the lining, but using material similar to that used in channel type furnaces an indefinitely long lining life is achieved. For copper-base alloys, definite figures cannot be given for lining life, but the change from one alloy to another is easily accomplished because of the simple form of the crucible, and because it is a very easy matter to remove the remains of the previous alloy and to clean the lining.

Refractory consumption in melting stainless steel varies from 2 to 4 kg./ton of alloyed steel at first installation, and about 5–6 kg./ton after repairs. These figures are for a 1½ ton furnace pouring at about 1,680° C. and melting a steel containing at least 6% chromium. For simple melting, without the addition of alloy materials, the figures would, of course, be slightly lower.

Reference was made earlier to the fact that a crack in the lining is more dangerous in the case of a high frequency furnace. This is a consequence of the fact that with mains frequency there is no melting action below a certain charge diameter. It follows then that metal in a lining crack is only heated by conduction from the bath and may solidify, whereas with high frequency the more nearly even small pieces approach the coil the greater is the heating effect.

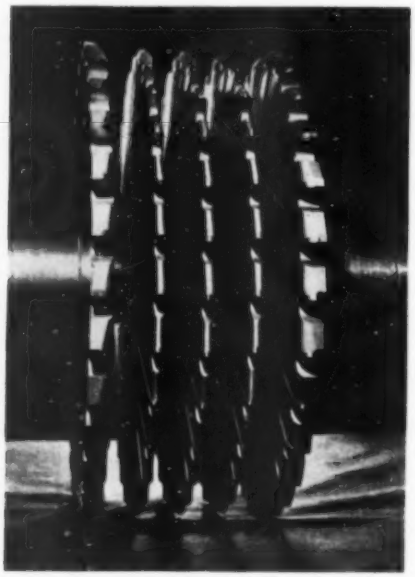
Metallurgical Development Work

One of the difficulties of trying to carry out refining in an induction furnace is the small surface area in contact with the slag, but there is a possibility of compensating for this by the stirring action. Furthermore, because the slag is cooler than the metal, the reaction is slower unless some supplementary form of heating is used. Experiments on these lines are in progress, and a further investigation concerns metallurgical work using an acid lining and briquettes. Some success has been achieved in attempts at desulphurisation.

Experiments with a basic lining are going on in the mains frequency furnace, as well as in high frequency units, but so far it has not proved economical. It is not possible to gain the real advantages of a basic lining, because of the difficulty of achieving satisfactory metal-slag reactions, as pointed out in the preceding paragraph.

Large Milling Cutter Gangs

EXTREMELY large milling cutter gangs for the machining of high tensile steel aircraft component parts are being supplied by English Steel Tool Corporation, Ltd., Manchester, to Vickers-Armstrongs (Aircraft), Ltd., Supermarine Works, Swindon. One of the gangs consists of two 15·200 in. diameter single angle cutters and three 14·952 in. diameter double equal angle cutters. Although they are not the largest cutters made by the company, they are amongst the largest solid high speed steel cutters of this type made in Great Britain.



Gang of five large milling cutters recently supplied by English Steel Tool Corporation, Ltd.

The important features of this gang were the angle of taper, the width of the cutters, and the steps between the cutter diameters, which all had to be controlled to exceedingly fine limits. This, plus the fact that the double angle cutters were of a rather slender section, tapering from 1·050 in. wide to a tip radius of 0·18 in., presented quite a challenge to the company's ability as cutter manufacturers.

At the design stage it was decided that as the bulk of the material would be removed by the tip radius, it was necessary to provide at that point a positive cutting rake which, when continued down the sides of the cutter, would supply the side teeth with the necessary shearing action, the depth of the cut being approximately 6 in. Moreover, to give all the teeth a positive rake would have made an already awkward proposition extremely difficult, so it was decided to have three equally-spaced teeth radial, i.e., with no rake. This accounts for the uneven spacing and lengths of the teeth towards the centre of the cutter.

On the shop floor careful attention was paid to the turning and milling operations, and special gauges and tackle were used to keep the amount of material to be removed at the grinding operation to a minimum. To help the grinding and inspection operations, a special inspection fixture was designed to check all the important elements of the cutters. Its principle was a master base, bushed to accept the cutters whilst still mounted on specially designed precision grinding arbors, and a sliding taper gauge which checked the angle of taper. The cutter chordal widths were controlled by measuring with block gauges the distance between the end of the taper gauge and the arbor. The most difficult operation, however, was the grinding, for not only had the cutters to be ground to size, but they had then to be sharpened to produce a cutting edge without reducing the dimension.

Molybdenum Disilicide for High Temperature Service

SEVERAL of the problems encountered in the service temperature range of 1,600–2,000° F. and above, may be solved by the use of molybdenum disilicide. This material has outstanding high temperature strength, corrosion and oxidation resistance, which point to its advantageous use in gas turbine blades, nozzles and parts subjected to similar service.

The material shows much promise for use in heating elements due to its high oxidation resistance at temperatures up to 3,000° F., and to its strength at temperature. For this application, room-temperature brittleness and high electrical conductivity of the material are drawbacks. A nominal composition of 75% $MoSi_2$–25% Al_2O_3 has shown good resistance to thermal shock and oxidation at temperatures up to about 2,700° F. Suggested applications include gas turbine parts, combustion chamber parts for jet engines and guided missiles, sand blast nozzles, kiln parts, hot-draw or hot-press dies, and industrial brazing fixtures.

Vapour deposition of silicon on molybdenum is one means of protecting molybdenum metal from oxidation. The coating consists mainly of an outer layer of $MoSi_2$ and an inner layer of MoSi. The coating is fairly hard but not fragile, and tests show that coated molybdenum filaments have operated at 1,800° F. for thousands of hours without decomposition.

Physical and mechanical properties of molybdenum disilicide bodies depend, to some degree, on the method of fabrication employed. Most parts are made by cold pressing and sintering or by hot pressing. The latter method is more satisfactory for fabricating dense bodies: molybdenum disilicide can be hot pressed to densities as high as 98·7% of theoretical. Temperatures currently used range between 2,700 and 3,000° F., with die pressures rising to 5,000 lb./sq. in. as temperatures increase. Moulded graphite or graphite-clay dies have been used successfully, since the graphite reacts with the pressed body to a depth of only 1 mil. below the surface. Limited work indicates that $MoSi_2$ can be extruded, rolled or moulded as ceramic clay, if first mixed with a suitable binder, such as corn flour, and enough water to form a stiff mass, then dried and sintered. However, no data are available on the shrinkage and strength of parts thus formed.

A silicide coating can be vapour deposited on molybdenum at 1,830–3,300° F. from a mixture of hydrogen and silicon tetrachloride. Two types of coating may be obtained, depending on the coating temperature. Below 2,500° F. the coating may be either two or three-phase, while at higher temperatures only $MoSi_2$ and MoSi are obtained, though a layer of molten silicon may be formed with high gas-flow rates, or with high concentrations of silicon tetrachloride. Molybdenum disilicide can be cast, though this is complicated by decomposition at the melting point, with loss of appreciable amounts of silicon.

Physical and mechanical properties of molybdenum disilicide bodies, prepared by both hot pressing and cold pressing and sintering methods, are given in the accompanying table. It will be noted that specimens have high short-time strength and outstanding oxidation resistance at temperatures of 2,000° F. and above. The long-time strength is superior to that of high temperature alloys and titanium carbide cermets.

TYPICAL PROPERTIES OF MOLYBDENUM DISILICIDE

Density (g./cc.)	About 6	
Hardness		
Cold Pressed and Sintered (Rc)	57	
Hot Pressed (Ra)	80–87	
Short Time Tensile Strength (lb./sq. in.)		
1,800° F.	40,000	
2,200° F.	42,800	
2,400° F.	41,000	
Compressive Strength (lb./sq. in.)	350,000	
Short Time Modulus of Rupture (Carbon Added) (lb./sq. in.)	Pressed and Sintered	Hot Pressed
1,800° F.	67,250	—
2,000° F.	86,250	72,000
2,200° F.	*	55,000
Stress Rupture Strength (100 hr.) (lb./sq. in.)		
1,800° F.	30,000	
1,900° F.	15,000	
2,000° F.	8,500	
Linear Coefficient of Thermal Expansion (80–2,700° F.) (in./in.)	$5{\cdot}1 \times 10^{-6}$	
Corrosion in Air (100–2,850° F.) (g./sq. cm./hr. max.)	$3{\cdot}1 \times 10^{-6}$	

* Test not applicable because bars showed too much plasticity.

No completely satisfactory metallic binder has yet been found. Cobalt, nickel and platinum wet the disilicide, but cannot exist in equilibrium with the material. Further work is necessary to find metals that will provide a ductile bond. Modulus of rupture of cermets made with molybdenum disilicide and various bonding metals are: hot pressed with cobalt, 60,000 lb./sq. in.; nickel-bonded 38,600 lb./sq. in.; platinum-bonded, 41,700 lb./sq. in.; and 75% $MoSi_2$–25% Al_2O_3, 22,000–30,000 lb./sq. in.

The ductility of the material changes with increasing temperature. At room temperature, $MoSi_2$ behaves in an elastic manner, with a brittle failure. At high temperatures, some plastic deformation takes place: at red heat, for example, siliconized molybdenum wire can be wound into tight coils without damage to the coating.

Poor thermal shock resistance is the major deficiency of molybdenum disilicide, and further work seems to be necessary before this material can be used in gas turbine blades. A series of tests on various ceramic and cermet materials showed that a 75% $MoSi_2$–25% Al_2O_3 cermet was superior to pure molybdenum disilicide, although it was inferior to titanium carbide with cobalt in this respect.

From *Materials and Methods* Jan., 1956, 131–133.

Standards Department Title Change

THE Board of Trade announce that their Standards Department has reverted to its former title of Standard Weights and Measures Department. The Standard Weights and Measures Department is responsible for the central administration of the Weights and Measures Acts and Regulations; and the Board consider the change of title desirable to prevent confusion between the functions of that Department and those of the British Standards Institution, which is concerned with the general standardisation of industrial products.

NEWS AND ANNOUNCEMENTS

Iron and Steel Institute A.G.M.

THE Eighty-Seventh Annual General Meeting of the Iron and Steel Institute will be held at the Royal Institution, Albemarle Street, London, S.W.1, and at the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1, on Wednesday and Thursday, 16th and 17th May, 1956.

To commemorate the centenary of the development of the Bessemer Process, Mr. JAMES MITCHELL, C.B.E., will give a Bessemer Centenary Lecture at the Royal Institution on Tuesday, May 15th, at 6.30 for 6.45 p.m. Admission will be by ticket only. The afternoon technical session on Wednesday, May 16th, will be devoted to the discussion of papers and presentation of a film on the Acid Bessemer Process.

Following the business meeting at the Royal Institution on Wednesday morning, DR. H. H. BURTON, C.B.E., will be inducted as President, and will deliver his Presidential Address. At 11.45 a.m., the Ninth Hatfield Memorial Lecture on "The Fracture of Metals" will be delivered by PROFESSOR N. F. MOTT, F.R.S.

The remaining technical sessions will be held at Grosvenor Gardens and the following papers will be presented for discussion :

Tuesday, May 15th

2.30 p.m.–4.30 p.m.

History and Practice of the Acid Bessemer Steelmaking Process in West Cumberland, by F. B. CAWLEY and D. R. WATTLEWORTH.

Control of the Acid Bessemer Process, by F. B. CAWLEY, J. G. GALEY and P. J. LEROY.

A colour film entitled "Steel Road" will also be shown.

Thursday, May 17th

9.45 a.m.–11 a.m.

Ingot Heat Conservation : Cooling of 15 ton Ingots between Teeming and Stripping, by L. H. W. SAVAGE and M. D. ASHTON.

Ingot Heat Conservation : The Cooling of Rimming-Steel Ingots between Teeming and Stripping, by M. D. ASHTON, R. F. PERKINS and L. H. W. SAVAGE.

11.15 a.m.–1.15 p.m.

The Effects of Gravity in the Solidification of Steel, by B. GRAY.

The Effect of Temperature and Pouring Speed on Ingot Structure, by THE INGOT COMMITTEE OF THE BRITISH IRON AND STEEL RESEARCH ASSOCIATION.

2.15 p.m.–3.45 p.m.

The Stress/Strain Curves of some Metals and Alloys at Low Temperatures and High Rates of Strain, by H. G. BARON.

Yield Behaviour of Metals at Low Temperature with particular reference to some Carbon and Low-Alloy Steels, by H. F. HALL and R. W. NICHOLS.

The Hardness of some Carbon and Low-Alloy Steels at Low Temperatures, by R. W. NICHOLS.

The Mechanical Properties of Carbon Steel Wire at Low Temperatures, by R. W. NICHOLS.

3.45 p.m.–4.45 p.m.

The Effect of Phosphorus Content on the Impact Value of Fully and Partially Hardened and Tempered Manganese-Molybdenum Steels, by N. P. ALLEN and C. C. EARLEY.

A Study of the Impact Properties of Boron-Treated Steel, by J. D. GRIMSLEY and S. J. ROSENBERG.

Non-Destructive Testing Symposium

THE Non-Destructive Testing Group of the Institute of Physics has arranged a Symposium on "Principles of Penetrant Methods," to be held at 6.30 p.m. on Friday, May 4th, 1956, in the Lecture Room at the Institute's House, 47, Belgrave Square, London, S.W.1.

Following an outline of the problems which have been encountered in the use of penetrant methods of industrial inspection, given by MR. H. L. CARSON, MR. W. G. COOK and DR. R. SCHNURMANN ; SIR ERIC RIDEAL, F.R.S., DR. E. W. J. MARDLES, MR. A. DE WAELE and DR. K. WEISSENBERG, will discuss the physics of the problems and the research needed for their solution.

Tickets may be obtained from the Deputy Secretary, The Institute of Physics, 47, Belgrave Square, London, S.W.1.

Non-Destructive Testing Summer Meeting

THE Summer Meeting of the Non-Destructive Testing Group of the Institute of Physics will be held at the H. H. Wills Physical Laboratory, Bristol, from July 11th to 14th, 1956, with the theme : "Physics of Some New Aspects of Non-Destructive Testing." The meeting is designed to stimulate an interest in the new techniques and ideas now being introduced into the broadening field of non-destructive inspection, and also to indicate the present limitations in our knowledge of the relationships between the physical properties and the mechanical behaviour of metals. The organisers hope that those familiar with non-destructive methods of flaw detection will welcome this opportunity of looking beyond the bounds of their existing techniques to the important developments foreshadowed by current researches.

After introductory contributions from DR. S. G. HOOKER, O.B.E. (Director and Chief Engineer, Bristol Aero-Engines, Ltd.), and DR. E. G. STANFORD (Aluminium Laboratories, Ltd.), papers will be presented on the following subjects : "Magnetic Properties and the Structure of Metals" ; "The Relationship between the Electrical Resistivity and the Mechanical Properties of some Aluminium Alloys" ; "The Principles and Applications of Nuclear Magnetic Resonance" ; "Optical Fluorescence in Non-Destructive Testing" ; "The Effects of Penetrating Radiations on Materials" ; "The Detection of Fatigue in Metals" ; "Structural Changes and Energy Dissipation during Fatigue in Copper" ; "Measurements of Elastic Constants by the Ultrasonic Pulse Method" ; and "Some Aspects of Testing Fibres."

Further particulars can be obtained from MR. R. S. SHARPE, (Honorary Secretary, Non-Destructive Testing Group of the Institute of Physics), Bristol-Aero Engines, Ltd., Filton House, Bristol.

Applied Mechanics Congress

The Ninth International Congress of Applied Mechanics will be held in Brussels in the buildings of the Universite Libre de Bruxelles from Wednesday, 5th September to Thursday, 13th September, 1956. The technical sessions will be organised in two sections ; the first dealing with fluid dynamics and aerodynamics ; and the second with mechanics of solids (rigid dynamics, vibrations, elasticity, plasticity). There are in addition to be several general lectures on subjects likely to be of interest

to members of both sections. Information concerning the Congress can be obtained from the General Secretary at Université Libre de Bruxelles, 50, Avenue F.D. Roosevelt, Brussels, Belgium.

Capper Pass Awards

THE Adjudicating Committee, representing the Councils of the Institution of Mining and Metallurgy and of the Institute of Metals, have made the following Capper Pass Awards in respect of papers published in the *Transactions of the Institution of Mining and Metallurgy* and the *Journal of the Institute of Metals* for the year 1955.

£100—DR. MAURICE COOK, MR. C. L. M. COWLEY and MR. E. R. BROADFIELD, for a paper on "The Use of Refractories in Low-Frequency Induction Furnaces for Melting Copper Alloys" (*J. Inst. Metals*, 1955, **83**, 295–305).

£100—MR. P. M. J. GRAY, for a paper on "The Extraction of Uranium from a Pyritic Ore by Acid Pressure Leaching" (*Trans. Inst. Min. Met.*, 1955, **65**, 55–64).

£50—MR. W. T. EDMUNDS and MR. R. C. LLOYD, for a paper on "The Production of Light-Alloy Drop Forgings, Their Heat-Treatment, Inspection and Testing" (*J. Inst. Metals*, 1955, **83**, 247–261).

The Capper Pass Awards are made from a fund placed at the disposal of the Councils of the two Societies by the Directors of Capper Pass and Son, Ltd., for the encouragement of the publication of scientific and technical papers dealing with processes and plant used in extraction metallurgy and on the subject of assaying and of papers and processes used in all branches of the non-ferrous metal industry.

Functions and Education of Welding Engineers

A CONFERENCE on "The Functions and Education of Welding Engineers" organised by the Institute of Welding will be held at Ashorne Hill from 16th to 18th September next. Some 22 papers have been promised and will be discussed in four sessions. The first group will deal with the "Functions of the Welding Engineer in Industry"; the second with "The Present Place of Welding in Advanced Technical Education in this Country"; and the third with "The Practice of other Countries", including the United States, France and Germany. In the last session a number of suggestions for the improvement of the facilities for the education of welding engineers will be described and discussed. It is expected that the Conference will attract, beside welding engineers, those concerned with technical management in the engineering industry, and teachers of engineering subjects from the universities and technical colleges.

Publication of Patents Abridgements

ONE of the services which the Patent Office renders to scientists and industry is the publication of abridgements of accepted patent specifications. These give essential particulars of such specifications in a very concise form, with line drawings where necessary, and show the trend of invention in the United Kingdom. They provide a quick and ready means of enabling inventors to find out whether their ideas have been anticipated. The abridgements are published in series of 20,000 specifications, divided into 44 groups, each group covering a field of invention. Initially they are sold in sets of sheets, each part consisting of 16 pages and containing about 50 abridgements. Individual volumes are then assembled and indexed by subject and name of applicant.

During the last war the publication of abridgements had to be suspended, but the Board of Trade announce that group volumes of specifications accepted during the war period are now on sale. This closes the gap between pre-war and post-war volumes, and a complete range of volumes is now available up to and including the 640,001–660,000 series, which includes specifications accepted and published prior to November, 1951. Abridgements in sheet form are also on sale in respect of specifications accepted and published prior to August, 1955.

The volumes in bound and sheet form can be obtained from the Sale Branch, Patent Office, 25, Southampton Buildings, Chancery Lane, London, W.C.2, at prices varying from £1 1s. 0d. to £1 10s. 0d. per group.

£2¼ Million Contract for Canada

THE BRITISH ALUMINIUM COMPANY'S subsidiary, the Canadian British Aluminium Co., Ltd., is placing contracts in this country for electric conversion equipment valued at over £2¼ million. The contract being placed with the British Thomson-Houston Co., Ltd., covers the supply of mercury arc pumpless steel tank rectifiers with associated transformers and switchgear, to the value of over £1¾ million; while the English Electric Company's contract will cover transformers and switchgear to the value of about £½ million. The equipment is required for the supply of direct current to furnaces for the electric smelting of aluminium.

The new smelting plant is to be built and operated by the Canadian British Aluminium Company, and will be situated at Baiecomeau, Province of Quebec. This is a township which has grown up since 1936 as the result of the building there of a paper mill by the Quebec North Shore Paper Company, who are partners with British Aluminium Company in the new aluminium development.

The contracts were obtained against keen overseas competition and, at a total installed capacity of 190,000 kW, constitute the largest order yet placed in the United Kingdom for rectifier conversion plant.

Ore Handling Plant for N.S.W. Steelworks

THE Fraser & Chalmers Engineering Works of The General Electric Co., Ltd., has received an order through its Australian associate, British General Electric Co. (Pty.), Ltd., for an ore handling and preparation plant for the Australian Iron & Steel Co., Ltd. This plant, which is for installation at Port Kembla Steelworks, New South Wales, will handle iron ore ranging in size from 4 in. cube to dust, at the rate of 800 tons per hour. Sinter conveying equipment is also included.

The plant comprises three main sections. The first deals with raw ore, which, arriving by rail, is dumped into bunkers, whence it is conveyed to an ore screening station. The larger products from screening are conveyed to bunkers for feeding the blast furnaces and open hearth furnaces, while the smaller fraction is conveyed to fourteen storage bunkers, each of 1,000 tons capacity. The second section deals with coke, limestone and flue dust

which, after screening, are stored in further bunkers. These materials, with the fine ore, are the components for sinter making. The third section of the plant comprises conveyors to take the materials from the bunkers, and deliver the mixture to the sinter machines.

The complete plant includes the 44 conveyors, 8 Gyrex screens, bunkers and all ancillary equipment. It is being designed by the Erith Works, which will also supply the mechanical equipment, while the structural steelwork will be manufactured in Australia.

New Tonnage Oxygen Project for Middlesbrough

An announcement of a tonnage oxygen project for Middlesbrough has been made by British Oxygen. This follows the news last October of a plant of this type to be built at Scunthorpe for the use of the Lincolnshire Steel Industry. Very large oxygen plants of the most up-to-date type will be installed on a site which has recently been acquired on Tees-side, and the plant installed initially will be capable of producing between 250 and 300 tons of oxygen per day. The installation will include a large tonnage oxygen gas plant, suitable for supplying not only the metallurgical requirements of the steelmakers in the area, but also their general purpose needs. This plant was only developed comparatively recently by British Oxygen, and it affords in operation a degree of flexibility which commends itself to the steelmaker in coping with his current problems of increasing demand. It is expected that the plant will be in operation early in 1957. Other plants on the site, however, will be put into operation before that date.

The advent of this large new oxygen-producing works is of particular interest at this time, when the steel industry is looking forward to yet more extensive production programmes in the immediate years ahead. The new works, in addition to providing oxygen and chemical gases for the local steel and chemical industries, will also serve other industries in the Middlesbrough area. Plans are also being made for a further phase of development on the new site, to cope with the continually growing demand for metallurgical oxygen.

Non-Ferrous Club A.G.M.

At the first Annual General Meeting of the Non-Ferrous Club, held at the Queen's Hotel, Birmingham, on March 14th, the Club's chairman, Mr. T. Basil Taylor, reviewed the growth of the Club since its inception a year ago. In that time it had advanced considerably and now had a membership of 109, representing all sections of the trade. At the eleven luncheon meetings, £143 13s. had been collected on behalf of various charities, and the Club could look forward to another successful year ahead. At the dinner which preceded the meeting, a further collection was taken on behalf of the Royal Metal Trades Pension and Benevolent Association, the sum of £23 being realised. Presenting his report as Treasurer, Mr. D. Devereux emphasised the importance of these collections on behalf of charity, and referred to the satisfactory financial position of the Club at the end of its first year, a balance of some £65 being carried forward.

In accordance with the rules, the committee resigned *en bloc* and the President and five members of committee were then elected as follows: *President:* Mr. W. Demel; *Committee:* Mr. R. Deutsch, Mr. T. B. Taylor, Mr. J. Turnbull, Mr. D. Devereux, Mr. G. Lewis. The new President, Mr. W. Demel, referred to the value of the social atmosphere created by a club such as this, and how much more pleasant it was to meet the people one would otherwise know only as a voice on the telephone. Business and all other relationships were improved if an atmosphere of friendship prevailed, and by cultivating friendship between members the Club could become a valuable force in the trade.

£1¼ Million Order for Davy-United

Rolling mill auxiliary equipment to the value of nearly £1¼ million has been ordered from Davy-United by John Summers & Sons, Ltd., for an extensive modification scheme at their Shotton Works, near Chester. Davy-United are to build a considerable amount of slabbing mill equipment, including ingot cars, ingot transfer car and make-up table at the ingot receiving table; scarfer entry table, scarfer entry and delivery side guards; trailing carriage and pinch rolls; a 1,350 ton hydraulic hot slab shear with auxiliaries; tables from the shear to the slab piler, piling equipment, and slab transfer car. For the following hot strip mill the new equipment required is also extensive. It includes pile receiving equipment, pile storage tables and depiling gear with pusher; furnace entry and delivery tables with entry skids, pushers and bumpers; much new roller table gear and side-guards, chutes, loopers and guides, as well as other auxiliaries. In all, over 4,000 tons of new machinery will be supplied. The contract forms an essential part of a large-scale development programme now being carried out by John Summers & Sons to raise the capacity of the Shotton Works to the point where it can deliver annually some 1,250,000 tons of finished products.

Coke Oven Plant Order

Woodall-Duckham Construction Co., Ltd., London, announces that it has received from Appleby-Frodingham Steel Co. (a Branch of the United Steel Co. Ltd.) an order valued at approximately £2 million for a further coke oven and by-product plant to be built at Scunthorpe. The contract includes two batteries each of 33 W-D Koppers coke ovens, with a daily coal carbonising capacity of 1,330 tons, duplicate oven machines, additions to the existing coal handling plant to supply the new ovens bunker, a new coke wharf and quenching station, additions to the existing coke handling plant, and a new primary by-product plant with extensions to the existing by-product and benzole plants.

National Foundry Craft Training Centre

There has been a change recently in the secretaryship of the National Foundry Craft Training Centre. The new secretaries are Heathcote & Coleman, and correspondence and applications to send apprentices to the Centre should now be addressed to that firm at 69, Harborne Road, Edgbaston, Birmingham, 15 (Tel: EDGbaston 4141).

Insurance Against Cadmium Poisoning

Following the acceptance by the Minister of Pensions and National Insurance of a recommendation by the Industrial Injuries Advisory Council, people whose occupations involve exposure to cadmium fumes will be insured under the Industrial Injuries Scheme against chronic, as well as acute, cadmium poisoning.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

40-Ton Stud Welding Steel

For many years there has been a demand from industry for stud welding attachments made of a material as readily weldable as mild steel, but having a greater tensile strength. Consequently, with the advent of low-alloy, high-tensile steels, such as Fortiweld, which are now being used extensively for industrial applications, tests were carried out to ascertain the suitability of such new materials for stud welding. These tests proved eminently worth while, and as a result, the Crompton Parkinson Stud Welding Organisation have now developed studs and attachments made of a high-tensile steel and weldable with the standard Cyc-Arc and Nelson stud welding equipments. Of particular interest to the user of such equipment is the fact that no special stud welding techniques are required, the present methods employed on mild steel being entirely suitable.

Typical chemical analyses of the types of steel employed for the studs shows a carbon content of 0·08–0·12% with 0·43% molybdenum and 0·0026–0·0046% boron added, giving a tensile strength of 42 tons/sq. in. and about 68% reduction of area. All stud welding tests carried out have proved that the welds are stronger than the studs themselves, and 90° bends showed no evidence of cracking. In addition to these excellent physical properties, the new stud material shows greatly increased fatigue and heat resistance, compared with the 0·35% carbon type of steel. The stress to rupture is still in the region of 26 tons/sq. in. after 1,000 hours at 500° C. Moreover, the material has a high ductility, which ensures high quality welds.

Already this new stud welding material is being used on the chassis of a well-known make of car. Another interesting development is in the use of 40-ton steel for stud welding plate headed studs on chemical vessels. These studs secure the refractory lining to the walls of the vessel, and the heat resisting properties of the material are thus fully utilised.

Subject to the availability of steel supplies, there is no difficulty in making any of the wide range of Crompton Parkinson stud weldable attachments in the new material. This fact will be of considerable interest to designers of high quality transformers, chemical equipment, etc. Furthermore, the new development will open up many new fields, such as the motor, aircraft and civil engineering industries, which, for many applications, insist on high-tensile steels for studs.

Crompton Parkinson, Ltd., Crompton House, Aldwych, London, W.C.2.

Diaphragm-Operated Control Valves

To meet the needs of process control systems where the pressure of the air supply is very low, the Baldwin Instrument Company has produced an operating mechanism which is sensitive to air pressures down to 1 lb./sq. in. This high sensitivity is obtained by mechanically coupling a large synthetic rubber diaphragm to the spool of the control valve. The pilot inlet connection is ¼ in. B.S.P. The system of unit construction on which

the Baldwin range of equipment is based makes it possible for the diaphragm operating mechanism to be fitted to ¼ in. and ½ in. bore, 2-, 3- and 4-way valves. The most common combination is to fit the diaphragm mechanism at one end of the valve and a return spring at the other. The other end of the spool can, however, be fitted to any of the 20 other standard operating mechanisms, including the diaphragm. Extensive tests have proved the reliability of this unit under the most arduous working conditions.

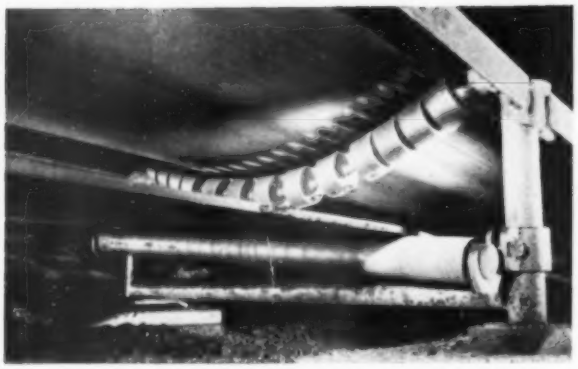
Baldwin Instrument Co., Ltd., Brooklands Works, Dartford, Kent.

Flexible Belt Conveyor Idler

A flexible belt conveyor idler which shapes itself to the load being carried and uses only two bearings is now available in Great Britain for the first time. Produced by Joy-Sullivan, Ltd., the mining machinery and equipment manufacturers, of Greenock, it is designed to prolong the life of belt conveyors in conditions and situations which have so far made their operation difficult. The idler is called the Limberoller, and was first produced by Joy-Sullivan's parent company in the United States, the Joy Manufacturing Company.

The Limberoller consists of a series of pressure moulded neoprene discs moulded to a neoprene sheathed flexible steel cable. This cable is freely suspended from two cadmium-plated precision type double row ball bearings to give a load-conforming catenary. The bearings are fitted with neoprene wiper seals and the edges of these run in annular grooves machined in the inner races. A cartridge type dustcap seals the blind side of each race. The bearings are charged and sealed with a long shelf-life grease which has a temperature tolerance of from −35° F. to +275° F.

The neoprene discs have flat resilient support surfaces which revolve at the same peripheral speed, giving perfect mating with the belt. Tough and durable, the discs have better abrasion resisting qualities than steel



rolls, and they will not support combustion. They resist most chemicals except extremely strong oxidising agents and aromatic hydrocarbons. Constant flexing reduces any tendency for material to build up on the belt. The training action helps to keep the belt in line and because of the positive contact between belt and discs belt wear is kept to a minimum.

The bearings are supported above and to each side of the belt, where they are out of the "danger zone" for abrasive and moisture attack. The position also ensures that no grease from the bearings gets on to the belt. An important factor is that the complete idler roller and bearing assembly can be changed without interrupting the flow of material, as it is not necessary to stop the belt for this purpose. The Limberoller also has self-cleaning properties due to the arrangement of the discs.

Two styles of stand are available. The LR.113 is 13½ in. or 16 in. high and has a tripod base. The type LR.102 has brackets for mounting on conventional sections. The former is arranged for the fitting of a return idler if desired, and this type may be added to a moving belt quite simply. There are no cross members between the two belt paths and this means that decking is not required. Should a piece of material fall on to the return belt, jamming is impossible because the only thing likely to be struck would be one of the idlers which would merely deflect and allow the piece to fall.

Limberollers and stands are available in three sizes, to take belt widths of 24 in., 30 in., and 36 in.

Joy-Sullivan, Ltd., Greenock.

Steelmakers' Blue Glasses

TRADITIONALLY, a blue glass of the cobalt type has been used by steelmakers when inspecting their furnaces. The requirements of these glasses have been that they are dark enough to reduce glare in the furnace to an acceptable level, and that they are of such a colour that the operator can judge accurately the temperature of his furnace. For this second requirement, a cobalt blue glass is ideal, since it has a high red and a high blue transmission and absorbs strongly the green and yellow.

It therefore enables the operator to estimate temperatures quite accurately using the two colour pyrometry effect. Use of the filter has, however, attendant hazards in that the glass transmits strongly in the ultra-violet and near infra-red regions of the spectrum, and both these radiations are, in sufficient quantity, harmful to the human eye.

At the request of the British Iron and Steel Research Association, Chance Brothers have developed a new glass, CSS, which is a compromise between the cobalt glass, with its high temperature discrimination properties, and a green glass with very poor temperature discrimination, but good protective properties. A transmission curve of CSS glass shows that it provides good protection against ultra-violet and infra-red radiation; its total heat transmission being 0·5%. Measurements have been made by the National Physical Laboratory of its efficiency as a means of estimating temperature differences. It is found that with a CSS filter of thickness 2·0 mm. the number of detectable chromaticity steps between a black body radiator at a temperature of 1750° K and one of 2000° K is 61. The corresponding number of steps for a cobalt blue glass of similar total transmission is 82.

Chance Brothers, Ltd., Smethwick, Birmingham 40.

Electronic Temperature Recorder

A NEW electronic temperature recorder developed by Fielden Electronics, Ltd., operates in conjunction with thermocouples and can be supplied for use with either base metal or precious metal thermocouples, in various ranges from 0–300° C. upwards. The instrument has been designed for industrial use and the motor driven pen is positioned by an electrical servo system from a high grade electrical meter. Automatic cold junction compensation is provided, and the equipment has an accuracy of ±1%. It is, therefore, suitable for use in many of the applications which would otherwise necessitate a D.C. potentiometer, for, although the accuracy is not quite as high as that obtained with the more expensive potentiometric equipment, it is adequate for the vast majority of industrial applications.

This recorder has been designed to give long trouble-free service and the mechanism has been kept as simple as possible. Gearing and moving mechanical parts have been cut down to a minimum and the simple electronic chassis itself is an interchangeable plug-in unit. The motor which drives the pen has ample power in reserve for operating alarm or control mechanisms, and for driving the large central indicating pointer, both of which facilities can be provided at a small extra cost.

Fielden Electronics Ltd., Wythenshawe, Manchester.

CURRENT LITERATURE

Book Notices

THE SAFE OPERATION OF BAR REELING AND STRAIGHTENING MACHINES

32 pp., numerous illustrations. Published by the British Iron and Steel Federation, Steel House, Tothill Street, London, S.W.1.

In July, 1954, a Sub-Committee of the Accident Prevention Committee of the British Iron and Steel Federation was set up under the chairmanship of Mr. W. W. Hickman, of Wolverhampton and Birchley Rolling Mills, Ltd., to investigate accidents occurring at reeling and straightening machines, and to try to find means to prevent them. The subject was chosen, in consultation with the Factory Department of the Ministry of Labour and National Service, as one of some importance, since it was considered that operatives on these machines were exposed to risks of accidents which, when they occurred, often resulted in serious injury.

Previous work on the subject was studied, and the makers of reeling and straightening machines were consulted. Examinations were made of the methods of operation and the types of work carried out in various works on different types of machines. Based on the information obtained in this way, conclusions have been reached on the risks to which the operator and others are exposed. These conclusions are set out in the report, and recommendations are made on effective methods of protection. Cost and production rate are considered, and estimates are made of the effect in these terms where the recommendations of the report are carried out.

ALUMINIUM IN CONTACT WITH OTHER MATERIALS

48 pp., numerous illustrations. Information Bulletin No. 21, The Aluminium Development Association, 33, Grosvenor Street, London, W.1. 2s.

The self-healing oxide film always present on aluminium gives it a very high natural resistance to corrosion which often renders surface protection unnecessary. When, however, it is used in connection with a second material, and under certain conditions, some simple precautions are required and become an element of good design and installation. This Bulletin describes briefly the causes and types of corrosive attack to the extent that is required, and then discusses the practical means of preventing corrosion, such as the use of inhibitors and jointing compounds, the method of cathodic protection, and the use of cladding and metal spraying, and refers to the advantages of all-aluminium construction.

An important section of the book describes the behaviour of aluminium in contact with specific materials which are listed under the sub-headings: iron and steel; non-ferrous metals; and non-metals. The recommendations are then given point by a section which describes their practical application in various fields, such as building and structural engineering, shipbuilding, mining, and electrical engineering.

Two important tables in this Bulletin show (1) an approximate grouping of aluminium and its alloys for exposure in rural, industrial and marine areas; and (2) the behaviour of couples, involving aluminium, when exposed to particular environments such as marine, industrial or conditions of total immersion. For readers interested in more fundamental principles, an Appendix deals briefly with the nature of metallic corrosion and includes a table of solution potentials of metals and intermetallic compounds.

BRAZING

28 pp., numerous illustrations. Published by The British Welding Research Association, 29 Park Crescent, London, W.1. 5s.

The British Welding Research Association, in conjunction with the lectures on increasing productivity through welding, which are being given at centres throughout the country, is producing a series of special booklets on welding processes for industry. The Association is enabled to do this by financial assistance from American funds made available through the Department of Scientific and Industrial Research.

The first booklet of the series, dealing with brazing, has been prepared by Mr. E. B. G. Trehearne, of the B.W.R.A. staff, who has had the benefit of the co-operation of Mr. E. V. Beatson and Mr. H. R. Brooker. Brazing is a modern production technique and is in the vanguard of modern cost-reducing methods. The booklet is directed not only to the designer or production engineer but also to the shop floor: it indicates the potentialities, methods, advantages and disadvantages, design considerations and practical points of the process. In its preparation much care and thought have been given to the inclusion of the maximum of useful information with the minimum of technicalities, and with economy of words.

Trade Publications

Beryllium copper has a number of advantages as a die material. These arise both from the properties of the finished die and from the techniques available for manufacture. We have recently received from Beryllium Smelting Co., Ltd., 36–38, Southampton Street, London, W.C.2, a leaflet dealing with this application of beryllium copper and particulars are given of its use in plastic moulds and dies, forging dies, steel forming and draw dies, titanium forming and draw dies, and zinc die casting dies. The same company has also issued a data sheet concerning the mechanical and physical properties of beryllium copper casting alloys, together with alloying instructions relevant to their production.

British Electro Metallurgical Co., a Division of Union Carbide, Ltd., has issued a loose-leaf catalogue containing details of the alloys and metals which Bemco and associated companies produce. They include alloys and compounds based on boron, calcium, chromium niobium (columbium), manganese, silicon, titanium, tungsten, vanadium and zirconium, as well as briquettes of chromium, manganese, silico-manganese and zirconium-silicon.

The February issue of *Quasi-Arc Mechanised Welding News* features an article on heavy girder fabrication, in which the Unionmelt submerged arc process is used. Other features concern automatic Sigma welding,

Fusarc welding of foundation columns, and the use of a Unionmelt flexible welding machine in the construction of an ingot bogie chassis.

In *Foseco Foundry Practice*, No. 123, an account is given of an investigation of a porous gun metal ring casting and further recommendations are made for overcoming shrinkage porosity in a pressure die cast aluminium washing machine pulsator, whose investigation was featured in an earlier issue. The present issue also contains features on bronze and gun metals, taper on patterns, trouble-free cupola slagging and loose-joint making.

Leaflet F.117, recently published by Evans Electroselenium, Ltd., 110, Potter Street, Harlow, Essex, describes the EEL Flame Photometer, which is a self-contained instrument for the accurate estimation of alkali metals in solutions. Full-scale deflection can be obtained with concentrates as low as 5 p.p.m. sodium, 10 p.p.m. potassium, 15 p.p.m. lithium and 50 p.p.m. calcium, but sensitivity control enables solutions of high concentration to be analysed.

Winn & Coales, Ltd., Denso House, Chapel Road, London, S.E.27, have recently issued a publication devoted to the protection of structural steelwork against corrosion, using their Denso products. These are mainly tapes of various types which are applied to the cleaned metal surface in such a way as to make a complete air and waterproof seal. Where it is desirable to avoid the accumulation of fluff or dust or to alter the appearance the coating can be painted.

When a brochure illustrating some of the blast furnace plants built by Ashmore, Benson, Pease & Co., Stockton-on-Tees, was published in 1950, it was announced that the Company intended to issue similar publications at five-yearly intervals. The second edition, *More Blast Furnaces*, has recently been published and features a number of installations in this country and abroad.

During recent years an increased demand has developed for large plant constructed in nickel and nickel-clad steel, and consequently for heating the metal in the course of fabricating this plant. This demand has emphasised the need for exceptional care when heating nickel, even though the workshops concerned are successfully handling other materials. Information gathered over a period of years from a large number of fabricators and users of nickel plant is included in a recent publication issued by The Mond Nickel Co., Ltd. Successive sections deal with attack by sulphur and oxygen on heated nickel; contamination of nickel surfaces before heating; cleaning procedures immediately prior to heating; contamination during heating; precautions during the heating of nickel; and techniques developed by fabricators.

The importance of the thermocouple as an aid to metallurgical industry and research is underlined by a comprehensive new booklet issued by Johnson, Matthey & Co., Ltd.—"Noble Metal Thermocouples," by H. E. Bennett, F.I.M. After brief surveys of methods of high temperature measurement and of the development of the thermocouple, the booklet goes on to deal with applications of the platinum metal thermocouple—with particular reference to its use in the steel industry—and with methods of calibration. A further section covers the properties of the platinum-group metals and their alloys in relation to the problems of temperature measurement, and, in addition, information is given on the principal causes of deterioration of thermocouples. Copies are available free on request from the company at 73–83, Hatton Garden, London, E.C.1.

Modern conditions call for metal parts to withstand service conditions at temperatures far in excess of those formerly experienced. To meet these conditions, Follsain-Wycliffe Foundries, Ltd., Lutterworth, Near Rugby, offer E.V. Heat Resisting Steel Castings for temperatures up to 1,175° C., and Wynite Heat Resisting Iron Castings for temperatures up to 600° C. A recently-published brochure gives particulars of these materials together with a guide to applications in various industries.

We have received from Alar, Ltd., a revised set of Specification Data Sheets for Cast Aluminium Alloys These sheets replace the original set dated 1949. The amendment has been made necessary by the revision of the Standard for Aluminium Casting Alloys (B.S. 1490) in November last year.

"Structures in Aluminium" is the title of an extensively illustrated brochure recently issued by Hawksley-S.M.D., Ltd., Slough. This publication illustrates pictorially the extent to which aluminium has established itself in the field of structural engineering. Buildings supplied by Hawksley-S.M.D. range from the prefabricated bungalows erected in all parts of the world to counteract the housing shortage, to schools, industrial storage buildings, office blocks, aircraft hangars, and a variety of structures to meet special applications.

We have received from L. Light & Co., Ltd., Poyle Trading Estate, Colnbrook, Bucks., the company's 1956 catalogue of organic research chemicals.

Books Received

"Handbook of Engineering Materials." Edited by D. F. Miner and J. B. Seastone. 1,380 pp. inc. index. New York and London, 1955. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 140s. net.

"Chromium-Nickel Austenitic Steels." By F. H. Keating. 138 pp. inc. index. London, 1956. Butterworths Scientific Publications in association with Imperial Chemical Industries, Ltd. 25s. By post 1s. 3d. extra.

"Electric Motors and Controls"—Electricity and Productivity Series, No. 3. 279 pp. inc. index and numerous illustrations. London, 1956. British Electrical Development Association. 9s. (post free).

"Micro-Indentation Hardness Testing." By B. W. Mott. 272 pp. inc. index and numerous illustrations. London, 1956. Butterworths Scientific Publications. 42s. By post 1s. 6d. extra.

"Metallurgical Thermochemistry." By O. Kubaschewski and E. Ll. Evans. Second edition (completely revised and reset). 410 pp. inc. subject and name indexes. London, 1956. Pergamon Press, Ltd. 55s. net.

"The Constitutional Diagrams of Alloys: A Bibliography." Institute of Metals Monograph and Report Series No. 2. Originally compiled by J. L. Haughton. Second edition compiled by A. Prince. 324 pp. London, 1956. Institute of Metals. 35s. net. ($5.50).

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

APRIL, 1956 Vol. LIII, No. 318

The Photometric Determination of Antimony in Tin and Tin-Lead Solder with Rhodamine B.

By W. C. Coppins, M.Sc., A.R.I.C. and J. W. Price, Ph.D., F.R.I.C.
Tin Research Institute, Greenford, Middlesex

A method for the determination of antimony in tin and tin-lead solders is described, which uses the colour reaction with rhodamine B without preliminary separation of either tin or lead.

ANTIMONY contents down to about 0·1% in tin and tin-lead solder may be conveniently determined by the volumetric method involving titration with standard potassium bromate solution. For smaller amounts volumetric methods are not very satisfactory, and an earlier publication by the present authors[1] described a procedure for the determination of both arsenic and antimony on a single sample of tin, using photometric methods. The procedure involved solution of the tin in concentrated sulphuric acid, addition of hydrochloric acid, and distillation of the arsenic as arsenious chloride. Antimony was then separated from the remaining solution by adding sodium hypophosphite and boiling with a copper coil, causing deposition of Cu_3Sb on the coil; after stripping, the antimony was finally determined photometrically as iodo-antimonite. If antimony only is to be determined, it is not essential to carry out a preliminary distillation of arsenic, since any arsenic is precipitated from the solution on heating with hypophosphite, and may be filtered off before introducing the copper coil. However, the method is less attractive when antimony only is required, and it is in any case somewhat tedious. During the two hour boiling period, small portions of the dark film of Cu_3Sb sometimes become detached from the coil, and there is the further danger that the film may be slightly dissolved during the subsequent washing if oxygen-free water is not used. In addition, the sensitivity of the iodo-antimonite reaction leaves something to be desired.

For these reasons an alternative method for determination of traces of antimony was sought, and from the point of view of sensitivity the colour reaction with rhodamine B seemed most attractive. This reaction was discovered by Fredrick[2], but the method described was not very satisfactory for quantitative work, owing to difficulties associated with destruction of excess rhodamine B. An improvement was made by Maren[3], who showed that the red antimony complex could be extracted with an organic solvent and determined photometrically. Several modifications of this method have appeared subsequently,[4-6] none of which has been completely satisfactory when applied to the determination of antimony in tin. Maren[4] reported some data which suggest that large amounts of tin[IV] suppress the formation of the antimony-rhodamine complex, but this cannot be the only factor, as application of this procedure gave erratic results even in the absence of tin.

More recently, Ward and Lakin[7] have described a modification which differs from all previous methods in that the antimony, as $SbCl_5$, is extracted by the organic solvent before reaction with the rhodamine B. These authors have shown that under certain conditions of acid concentration rhodamine B may itself be extracted into the organic solvent to give a coloured solution, and have taken appropriate steps to eliminate this effect. Ward and Lakin's procedure has been used successfully for determination of antimony in organic compounds following separation of the metal with diethylammonium diethyldithiocarbamate[8], and results given below show that it can be satisfactorily applied to the determination of antimony in tin and tin-lead solder without preliminary separation of either tin or lead.

Reagents

(1) *Sodium Metabisulphite Solution*—1% freshly prepared.

(2) *Ceric Sulphate Solution.*—Dissolve 3·3 g. ceric sulphate, by warming with 100 ml. N sulphuric acid, and filter.

(3) *Hydroxylamine Hydrochloride Solution*—1% freshly prepared.

(4) *Rhodamine B Solution*—Dissolve 0·02 g. rhodamine B in 100 ml. N hydrochloric acid.

Method

Dissolve 0·5 g. sample by heating with 10 ml. concentrated sulphuric acid and allow to cool. Add 30 ml. water and cool again, then add 50 ml. concentrated hydrochloric acid. If necessary, warm on a hot plate (do not boil) until any lead sulphate has dissolved. Cool, transfer to a 100 ml. graduated flask and dilute to the mark with water. Pipette a 10 ml. aliquot into a separating funnel and add 0·5 ml. sodium metabisulphite solution. Cool to below 25° C. and add 3 ml. ceric sulphate solution, followed by 0·5 ml. hydroxylamine hydrochloride solution. Allow to stand until the ceric sulphate is reduced and then dilute to 60 ml. Add 10

TABLE I.—ANTIMONY IN TIN.

Sample	Antimony Present (%)	Antimony Found (%)
N.B.S. 431	0·19	0·18
,, 432	0·095	0·10
,, 433	0·050	0·044
,, 434	0·019	0·017
,, 435	0·010	0·009
B.C.S. 192C	0·018	0·015

TABLE II.—ANTIMONY IN TIN-LEAD.

Weight of N.B.S. 127 (mg.)	Equivalent Antimony (%)	Antimony Found (%)
72·8	0·109	0·108
52·0	0·078	0·083
25·0	0·038	0·040
12·7	0·019	0·021

ml. isopropyl ether and shake 30 seconds. Allow to separate and run off the aqueous layer. Wash twice with 2 ml. portions of N hydrochloric acid, discarding the aqueous layer each time. Finally add 2 ml. rhodamine B solution and shake 10 seconds. Allow to separate, discard the aqueous layer (this should still be coloured red; if colourless, a smaller aliquot of the original solution must be used) and run the isopropyl ether layer into a small stoppered bottle through a roll of filter paper inserted into the stem of the funnel. Measure the optical density in a spectrophotometer using a 1 or 2 cm. cell and wave-length 550 mμ.

The above procedure is suitable for antimony contents in the range 0·001–0·025%. For higher contents use a smaller aliquot and dilute to 10 ml. with 1 : 1 hydrochloric acid before adding the sodium metabisulphite, or use a smaller sample weight.

Calibration

Dissolve 0·12 g. pure antimony in 5 ml. concentrated sulphuric acid, allow to cool and dilute with 15 ml. water. Cool again and add 50 ml. concentrated hydrochloric acid. Transfer to a 100 ml. flask and dilute to the mark. 1 ml. = 1·2 mg. antimony. Dilute a portion of this solution with concentrated hydrochloric acid so that 1 ml. contains 0·0024 mg. antimony. Measure out 1–5 ml. portions of this solution into five separating funnels and dilute each to 5 ml. with concentrated hydrochloric acid. Add 5 ml. water and 0·5 ml. sodium metabisulphite solution and continue as above. This range is suitable for the 1 cm. cell. For the 2 cm. cell a standard solution containing 0·0012 mg. antimony per ml. should be used.

Discussion and Results

The antimony is required in the pentavalent condition and ceric sulphate is used to oxidise antimony^{III} to antimony^{V}. The purpose of the preliminary reduction with sulphite is to reduce any antimony^{IV} to antimony^{III}, since the former is not oxidised by ceric sulphate. When tin is dissolved in concentrated sulphuric acid, any antimony present is normally obtained in the trivalent form and the reduction with sulphite should not be necessary. However, this step has been retained as a precaution. It is important to keep the temperature below 25° C. during the oxidation and extraction of antimony since under certain circumstances, hot hydrochloric acid can react with both the ceric ion and isopropyl ether, and if these reactions occur oxidation of antimony may be incomplete.[7] There is slight interference from arsenic, but an arsenic content at least 100 times that of the antimony can be tolerated.

The method was tested on the set of five standard spectrographic samples of tin supplied by the National Bureau of Standards, and on the single British Chemical Standard sample of pure tin No. 192C. At first the preparation of the samples presented some difficulty. Samples of some of the N.B.S. Standards were dissolved in 5 ml. sulphuric acid and after cooling and diluting, 5 ml. hydrochloric acid were added and the solutions were made up to 50 ml. From these 5 ml. aliquots were taken, the acidity adjusted to 1 : 1 with respect to hydrochloric acid, and Ward and Lakin's procedure was applied. This led to low results and it was thought that the 5 ml. of hydrochloric acid might be insufficient to prevent hydrolysis of some of the antimony on diluting to 50 ml. The cooled sulphuric acid solutions were therefore diluted to 100 ml. with 1 : 1 hydrochloric acid and 10 ml. aliquots were used. These gave much better results, but some low values were still obtained. It was considered that this was possibly due to loss of antimony as the volatile chloride on adding 1 : 1 hydrochloric acid to the sulphuric acid; the evolution of heat caused by the first addition of hydrochloric acid did in fact give rise to a considerable amount of hydrogen chloride fumes. This was avoided by diluting the sulphuric acid with water and cooling before adding the hydrochloric acid, and with this modification the results shown in Table I were obtained.

The only standard sample of tin-lead solder available (National Bureau of Standards No. 127) contained 0·75% antimony, which was outside the range under investigation. A sample of antimony-free solder was therefore prepared by melting together equal weights of the purest available tin and lead; a determination by the rhodamine B method showed well under 0·001% antimony in the resulting alloy. 0·5 g. samples of this alloy were then dissolved, together with carefully weighed amounts of N.B.S. 127 to give antimony contents in the required range. The results obtained on these composite samples are shown in Table II.

Acknowledgment

This work was carried out in the laboratories of the Tin Research Institute, and the authors are indebted to the International Tin Research Council for permission to publish.

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Correction

THE ISOLATION OF SILICON NITRIDE FROM A COMMERCIAL 4% SILICON STEEL

We regret that a typographical error appeared in the letter on the above subject which appeared in our March issue, above the signature of MR. H. A. SLOMAN. On page 136, column 2, line 2, the words "acid-soluble" should read "acid-insoluble."

Change of Address

THE address of West Instrument Ltd., is now 52, Regent Street, Brighton, 1, Sussex (Tel.: Brighton 28106).

Liquid-Liquid Extraction Procedures in Inorganic Analysis

A Review of Practical Applications with Particular Reference to Metallurgical Analysis

By T. S. West, B.Sc., Ph.D., A.R.I.C.

Department of Chemistry, University of Birmingham

The growing complexity of modern materials has led to difficulties in their chemical analysis resulting from the increasing multiplicity of other substances accompanying the constituent to be determined. The development of new separation methods has made possible the continued use of classical analytical procedures in the face of increasing competition from physical methods, and in the present series of articles the author surveys liquid-liquid solvent extraction techniques in inorganic analysis, with particular reference to metallurgical analysis. In the third of the series the author discusses the extraction of Group III metals.

(*Continued from page* 134 *of the March issue of* METALLURGIA)

EXTRACTION OF GROUP III METALS (Al, Ga, In, Tl, and Rare Earths)

Aluminium

ALUMINIUM is resistant to extraction from aqueous solution as a purely inorganic compound. In this respect it differs from the other metals of Group III, all of which can be extracted as their halides by diethyl ether. It is almost completely unextracted as its nitrate. Fischer and Bock[42] found that some 49% of the aluminium content of a 0·5 N hydrochloric acid solution containing 53% ammonium thiocyanate was extracted by an equal volume of diethyl ether. This extraction of the thiocyanate by diethyl ether is in marked contrast to more recent work by Aven and Freiser,[43] who used an extraction by tributyl phosphate at *p*H 1 from thiocyanate solution to remove iron from an aqueous solution containing aluminium. The aluminium was subsequently determined, and there was found to be no loss. Indeed, the separation was claimed to be superior to that obtained by extracting the iron as chloride by diethyl ether or diisopropyl ether.

The extraction of aluminium as its chelate compound with oxine by chloroform is complete between *p*H 4·3–4·6, but falls off at higher *p*H values.[15] If, however, a more concentrated solution of oxine in chloroform is used, a much wider *p*H range is permissible. Thus, using a 1% solution as opposed to the seven times more dilute reagent used above, Gentry and Sherrington[16] obtained quantitative extraction over the ranges 4·8–6·7 and 8·2–11·5 on 50–200 μg. samples of aluminium. Many other metals unfortunately extract over the same *p*H ranges, and this problem has recently been examined by Margerum, Sprain and Banks,[44] who were concerned with the evolution of a spectrophotometric method for determining aluminium after extraction with oxine and chloroform. The extraction of thorium was prevented by masking with 4-sulphobenzenearsonic acid in an ammonium acetate/acetic acid buffer, whilst small amounts of iron were masked by the use of 1, 10–phenanthroline in the absence of perchlorate. Copper, zinc, cobalt and nickel, which extracted with the aluminium under these conditions, were stripped from the chloroform layer by washing with alkali cyanide. Beryllium, magnesium and the alkaline earth metals do not extract under the conditions favourable to aluminium.

Small amounts of aluminium are completely extracted at *p*H 2–5 by cupferron plus chloroform,[17] but dithizone has no action. Miller and Chalmers[45] have recently made use of the solubility of the acetyl acetone complex of aluminium in ether in a procedure for the analysis of silicate rocks. An initial cupferron extraction from fairly acid solution removed iron and titanium, etc. In the acetyl acetone extraction, beryllium and aluminium were separated from calcium, magnesium, and manganese, etc. Examining the earlier work of Stene,[46] who separated aluminium, iron, beryllium, cerium and copper from calcium, magnesium, manganese, titanium, cobalt, nickel, zinc, uranium, etc., by extraction of the acetyl acetonates with carbon tetrachloride at *p*H 4·5–7·5, Miller and Chalmers found diethyl ether to be superior to the halogenated hydrocarbons as solvent for the complex, giving complete removal of the aluminium in three extractions at *p*H 6–7. Attempts to recover the

ETHER EXTRACTION OF VARIOUS METALS FROM HYDROCHLORIC ACID SOLUTIONS CONTAINING 53% AMMONIUM THIOCYANATE[43]

Metal	% Extraction	
	0·5 N Acid	*p*H 3·5
Beryllium	50	—
Magnesium	0·02	0·02
Calcium	0·04	0·06
Aluminium	48·9	37·1
Indium	59·2	64·9
Scandium	94·1	74·2
Yttrium Earths	0·07	0·07
Lanthanum	0·002	0·001
Titanium^{IV}	2·4*	—
Zirconium	0·034	0·001†
Thorium	0·13	0·06
Uranium^{VI}	4·6	2·3‡
Manganese	0·17	0·14
Iron^{III}	51·8	42·8

* Acidity 3–1·0 N.
† Actually measured at *p*H 0·9.
‡ Neutral solution not *p*H 3·5.

aluminium by evaporation of the solvent led to loss of the aluminium by volatilisation of the chelate, but the metal was easily recovered by back extraction into aqueous 6 N hydrochloric acid.

Gallium

Gallium chloride is readily extracted from aqueous solution by diethyl ether at an acidity of 6 N. By this means, gallium may be separated from aluminium, indium, magnesium, etc., but not from iron[III], gold, thallium[III], germanium, molybdenum, arsenic, antimony, or tin. The distribution coefficient is approximately 17. Grahame and Seaborg[47] reported that the distribution of gallium chloride in the range 10^{-12}–10^{-3} M was independent of concentration, but Swift[48] found that the extraction was much more favourable at higher gallium concentrations. In a more detailed study of the diisopropyl ether extraction, it has been shown that equimolecular amounts of $GaCl_3$ and HCl are extracted from hydrochloric acid solutions not greater than 7 N. In more concentrated acid, the $HCl/GaCl_3$ ratio is greater than unity, and at acidities of 8–9 N an increase in the concentration of gallium chloride causes the separation of a third phase, which is intermediate in density between the aqueous and ether phase and is formed at the expense of the latter. Nachtreib and Fryxell[49] attributed the formula $HGaCl_4$ to the compound extracted from solutions not greater than 7 M with respect to hydrochloric acid, and stated that the optimum acidity in using diisopropyl ether is 7·2 M. According to Wada and Ishii,[50] gallium is not extracted from hydrobromic acid by diethyl ether at acidities below 2 N. At an acidity of 4 N, only 3·6% of gallium is extracted, but in 5 N acid 50% is removed. Kitahara[36] has shown that no gallium is extracted by diethyl ether from 6·9 N hydriodic acid, or from hydrofluoric acid,[37] but he quotes 81% extraction from hydrobromic acid solution.

The gallium chelate of 8-hydroxyquinoline can be extracted from aqueous solution at *p*H 2·6–3·0 by chloroform. This provides a useful separation from aluminium, but not from indium.[29] The extract has a strong yellow fluorescence. Moeller and Cohen[51] have more recently found that the extraction is complete from *p*H 3–6·2, when a fourfold excess of the reagent in chloroform is shaken with the aqueous solution of gallium. Dithizone does not extract gallium, and Furman and his co-workers make no mention of its extraction with cupferron.[17]

Indium

Like aluminium, indium may not be extracted from hydrochloric acid solution, and as mentioned previously this may be used to ensure separation from gallium, iron and other metals which form extractable chlorides. Indium is, however, readily extracted from bromide solutions by solvents such as diethyl ether. Thus, whereas only a small amount of gallium (3·6%) is extracted from 4 N hydrobromic acid, 99% of indium is removed. In 3 N hydrobromic acid, the corresponding figures are 0·3% and 89·3%. From 6·9 N hydriodic acid, indium is extracted to some extent (7·9%), whereas gallium is not removed at all.[36] Recently, Irving and Rossotti[38] have shown that the extraction of gallium is quantitative over the range 0·5–2·5 N hydriodic acid, when diethyl ether is used as solvent, whereas indium remains in the aqueous phase. No marked change in the percentage extraction is observed in the range 0·026 M–$5{\cdot}4 \times 10^{-6}$ M indium when the other conditions are not varied. At 1·5 N acidity, 99·9% extraction of indium iodide is found. Cyanide, fluoride, citrate, and phosphate do not interfere with the extraction, but considerable amounts of chloride ion slightly reduce the recovery. Fischer and Bock[42] reported that 59% of the indium content of a 0·5 N hydrochloric acid solution containing 53% w/v of ammonium thiocyanate was extracted by shaking it with an equal volume of ether.

According to Furman and his co-workers,[17] the indium salt of cupferron is soluble in benzene and chloroform, but no definite information is given on the subject of direct extraction of indium from aqueous solutions by this method. Moeller[52] found that indium can be completely extracted from aqueous solutions in the *p*H range 3·2–4·5 by shaking with a chloroform solution of oxine. At this *p*H, aluminium, tin[II], bismuth, iron, cobalt, nickel and copper are extracted, but separation can be effected from magnesium, calcium, strontium, zinc, cadmium, mercury[II], tin[IV], lead, manganese, chromium and silver. In a procedure for the polarographic determination of indium in beryllium compounds, Milner[53] made use of the extraction of indium by oxine in chloroform to separate it from elements such as cadmium (which has a polarographic wave coinciding with that of indium) and others which interfere by being reduced at more positive potentials. The indium and other metals were recovered by destroying the organic matter with sulphuric/nitric acid, and iron and molybdenum which still remained to interfere were extracted by ether from a hydrochloric acid medium. As noted previously, a partial separation of indium from gallium is possible by the oxine method. Dithizone in chloroform extracts indium from aqueous solutions buffered at *p*H 5–6 but the conditions are rather critical. Cyanide may be used to prevent the extraction of most other dithizonates.

ETHER EXTRACTION OF METALS FROM HYDROBROMIC AND HYDRIODIC ACID SOLUTIONS

Metal	% Extraction	
	Hydrobromic Acid	Hydriodic Acid
Antimony[III]	0	100
Bismuth	0	34·3
Cadmium	0	100
Gallium	81	0
Indium	99·4	7·8
Iron[III]	4·8	—
Mercury[II]	0	100
Molybdenum[VI]	6	3·5
Tin[II]	—	100
Zinc	0·2	10·6
Iridium[IV]	7	0
Other Platinum Metals	0	0

The data in this table were obtained from S. Kitahara. *Repts. Sci. Res. Inst. (Japan)*, 1949, **25**, 165.

Thallium

Thallium is extracted to some extent from 50% nitric acid by diethyl ether. In the trivalent state, 7·7% is extracted, but only minute amounts are removed when the thallium is in its lower valency form. From 6 N hydrochloric acid, diethyl ether extracts 90–95% of thallic chloride, but does not remove thallous chloride. Thallic chloride is virtually completely extracted over the range 0·1–5 N hydrochloric acid, and this feature is useful in providing a means of separation from other metals, such as iron and gallium, which are also extracted at higher acidities, but not from dilute acid. Thallium[III] bromide is extracted over a wide range of acid concentrations by diethyl ether, but no information could be

found with regard to extraction of the thiocyanate, although it is very probable that this can easily be effected. According to Wada and Ishii,[50] the extraction of thallic bromide from 0·1 N hydrobromic acid solution permits thallium to be completely separated from all metals except gold. The extraction of thallic iodide from a dilute solution of hydriodic acid by diethyl ether is complete even when only minute amounts of thallium are present in the solution.

According to Sandell,[29] thallium may be extracted from aqueous solution in either valency state by means of dithizone in carbon tetrachloride. In the trivalent state, however, the reaction is not complete, and the dithizone is oxidised by the thallium. On the other hand, monovalent thallium is extracted quantitatively over the *p*H range 9–12. When the extraction is carried out from alkali cyanide medium, only lead, bismuth, and tin[II] accompany the thallium. There is, however, perceptible co-extraction of manganese and, according to Haddock,[54] large amounts of zinc, mercury, and nickel decrease the efficiency of extraction.

The oxine derivatives of thallium[I] and thallium[III] are soluble in chloroform. Moeller and Cohen[51] found that the extraction of thallium from aqueous solution using a solution of oxine in chloroform did not become appreciable at *p*H values less than 6, and they established that optimum extraction occurred in the narrow region from *p*H 6·5 to *p*H 7·0, although even there extraction was incomplete.

The Rare Earths

Appleton and Selwood[1] have made a fairly extensive investigation of the solvent extraction of rare earths as their chlorides, iodides, nitrates, thiocyanates, citrates, lactates, glycollates and acetyl acetonates by solvents such as hydrocarbons, ketones, ethers, esters, and alcohols. Being concerned mainly with the evolution of a method for separating the rare earths by using a countercurrent partition device, the authors rejected the extraction of the nitrates by mixtures of acetone and ether, etc., because the densities of the layers were very similar, whilst they regarded the extraction by acetyl acetone in benzene as being not suited to such a method on account of the instability of the system.

The thiocyanate of neodymium is very soluble in *n*-butanol, and although the solvent is appreciably soluble in water, Appleton and Selwood considered it to offer the best hope of successfully separating the rare earths. As a result of their investigations they reported a separation factor of 1·06 between lanthanum and neodymium. The neodymium concentrates in the organic layer.

Templeton and Petersen[56] examined the distribution of the nitrates of cerium, lanthanum and neodymium between *n*-hexanol and an aqueous phase. They established that the aqueous phase required to be about 90% saturated before appreciable extraction occurred. Starting with 50 g. of mixed oxides containing 50·7% Nd_2O_3, they obtained a yield of 9 g. of 69% Nd_2O_3 in three stages, claiming an overall separation factor of 2·14. The distribution of the rare earth nitrates between water and *n*-hexanol was further examined by Templeton.[57] From the data on cerium[III], lanthanum, praesodymium, neodymium and samarium, he concluded that cerous nitrate is less readily extracted than lanthanum nitrate, but for the other rare earths investigated, the extractability increased with the atomic number.

More recently Asselin, Audrieth and Comings[58] have reported on the solvent separation of the rare earths from thorium by extraction of the rare earth nitrates into 1-pentanol from aqueous solution containing ammonium thiocyanate. Since the ionic radii of the rare earths decreased with increasing mass, it was anticipated that the salts of the heavier rare earths would be less ionic in character and, therefore, more soluble in organic solvents than the lighter ones. Secondly, with increasing mass and nuclear change, the rare earths might be expected to display an increasingly greater tendency to complex formation, both cationic and anionic; and since such complexes are generally more soluble in non-polar solvents than simple ionic compounds, it was expected that the differences in solubility among the rare earths anticipated by the first hypothesis would thereby be augmented. Of several solvents examined, only 1-butanol and 1-pentanol extracted satisfactory amounts of rare earth salts. The former was preferred since it extracted larger amounts of the salts with no great difference in selectivity. The extraction of chlorides was poor, whereas nitrates were readily extracted, but, contrary to expectations, the lighter earths were more readily extracted than the heavier ones. As expected, addition of ammonium thiocyanate increased the degree of extraction, but the solubility of the butanol in the aqueous phase became appreciable. With concentrated ammonium thiocyanate solutions, the butanol became completely miscible. Under these conditions, 1-pentanol gave the same degree of extraction as 1-butanol in the absence of thiocyanate, but the order of extractability of the rare earths remained the same, so that no conclusions could be drawn as to whether or not the heavy rare earths form complexes more readily than the lighter ones.

Thorium is extracted by butanol to a much less extent than the rare earths, but in the presence of thiocyanate and using 1-pentanol this position is reversed. The authors consider this to be strong evidence for the formation of some type of thiocyanate complex by the thorium. In summing up the position, Asselin, Audrieth and Comings give the order of extractability of the nitrates as neodymium > yttrium > thorium, with sufficient differences in the behaviour of the various earths to offer possibilities of separation. From ammonium thiocyanate solution, 1-pentanol extracts thorium much more readily than the rare earths, so that a very effective means of separation from the rare earths is available.

The extraction of the lanthanides into tributylphosphate (T.B.P.) has been made the subject of a recent study by Peppard and his co-workers.[55, 59] From aqueous hydrochloric acid and 8–15 N nitric acid, the extractability of the rare earths increases with the atomic number, paralleling the theoretical order of decreasing basicity. The order is inverted for the system T.B.P./0·3 M nitric acid. Yttrium falls in the position predicted from ionic radii, and the logarithms of the distribution ratios of a given pair of lanthanides diverge with increasing acidity for relatively concentrated nitric acid solutions, so that the theoretical maximum mutual separation of the pairs requires the use of concentrated nitric acid solution. The result of adding an inert diluent to the T.B.P. is to decrease the extractability of the rare earths by a factor much larger than can be accounted for by simple dilution. The lanthanides may be divided into two groups, the division occurring at any predetermined point by control of certain variables in

countercurrent fractionation. In this way Peppard *et al* accomplished the isolation of a thulium/lutecium fraction from a mixed rare earth source. The authors point out that by means of two successive divisions any individual lanthanide may, in principle, be divided from its neighbour on either side. Scandium may be separated from the lanthanides and yttrium by extraction from hydrochloric acid. These separations were carried out on a tracer scale, but Weaver, Kappelmann and Topp[60] applied the method in a large scale countercurrent extraction apparatus to isolate a kilogram of 95% Gd_2O_3 from a mixture of rare earths. Scadden and Ballou[61] have reported that in carrier concentrations a separation of the yttrium and lanthanum groups is effected by extraction with a 0·6 M solution of di-*n*-butyl phosphoric acid in *n*-butyl ether. Yttrium and holmium are about 95% extracted, while lanthanum and cerium are only about 2% extracted.

The extraction of the 8-hydroxyquinoline derivatives of the rare earths by chloroform is incomplete, but Moeller and Jackson[62] found that the 5,7-dichloro-8-hydroxyquinoline chelates were easily extracted at controlled *p*H values. Inasmuch as the 5,7-dichloro compound is a stronger acid than the parent substance, its metal derivatives might be expected to more ionic and, therefore, less readily soluble in the organic solvent. The apparent anomaly is ascribed to the reduced solubility of the dichloro chelates and their consequent resistance to hydrolysis which would decrease the extent of extraction. The extraction is dependent on factors such as temperature, *p*H of the aqueous phase, and relative concentration of the reactants. Below *p*H 5–6, no extraction of the rare earths occurs. Neodymium begins to extract at *p*H 6·1 and is completely extracted above *p*H 9·4. Erbium begins to extract *ca* *p*H 5 and extraction is complete above *p*H 8·3. The authors reason that the extraction of the earths intermediate between neodymium and erbium will be complete within the range 8·3–9·4. The overlap in the extraction ranges shows clearly that separations of the rare earth metals by extraction with 5,7 dichloro-8-hydroxyquinoline and chloroform on anything but a fractional basis are impractical. Information on the extraction of the cupferrates of the rare earths is scanty, but it is known that the reddish-white precipitate formed by adding cupferron to a neodymium solution is insoluble in organic solvents, and similarly the compound with cerium^{III} is insoluble, although the compound formed with quadrivalent cerium is easily soluble in several organic solvents.[17]

Imre[63] showed that cerium^{IV} nitrate was extracted by diethyl ether from strong nitric acid solutions, but the method has the disadvantage that an exothermic reaction takes place with considerable attack on the solvent. The problem was taken up subsequently by Warf,[64] who examined several solvents which would be expected to be resistant to the strong oxidising action of the system. Tri-*n*-butyl phosphate was found to be most satisfactory, 98–99% of the cerium^{IV} entering the organic phase when equal phase volumes were used, irrespective of nitric acid or ammonium nitrate concentration. The nitric acid promoted easy separation of the layers and only at extreme dilution (0·001 F nitric acid) did the extraction fall off. A small percentage of the cerium^{IV} was reduced to the trivalent state in the extraction. The presence of ammonium sulphate was found to interfere seriously, but use was made of this factor in recovering cerium^{IV} from the solvent layer. It was found, however, that back extraction of the cerium^{IV} could be more efficiently done by shaking the extract with aqueous hydrogen peroxide when the cerium^{IV} was reduced and quantitatively transferred to the aqueous phase. Some tributyl phosphate accompanies the cerium^{III} into the aqueous solution, but it can be removed by shaking with benzene. Uranyl and thorium nitrates are extracted by the tributylphosphate, but these can be separated by initial extraction from cerous solution. Addition of potassium bromate and continuous extraction then gives complete recovery of the cerium. The method provides an excellent separation from iron, fair separation from zirconium, but poor separation from lanthanum.

(To be continued)

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THE DAVID BROWN CORPORATION, LTD., has formed a new subsidiary, David Brown Industries, Ltd., to unify and consolidate the manufacturing activities hitherto carried on by the following units: David Brown & Sons (Huddersfield), Ltd.; The David Brown Foundries Co.; The David Brown Tool Co.; The Keighley Gear Co.; The Coventry Gear Co.; David Brown-Jackson, Ltd.; David Brown Gears (London), Ltd.; David Brown Machine Tools, Ltd.; David Brown Tractors (Engineering), Ltd. These new arrangements do not affect Aston Martin, Ltd., Lagonda, Ltd., Harrison, McGregor & Guest, Ltd., and Tickford, Ltd., which continue to operate as at present.

Aluminium Stamp

BELIEVED to be the first of its kind in the world, the Hungarian Post Office has recently issued an aluminium stamp in honour of the twentieth anniversary of the foundation of the country's aluminium industry. Printed on aluminium foil mounted on paper, it is an air mail issue of 5 forints value, and incorporates a view of Budapest's principal industrial centre—Coepel Island.